

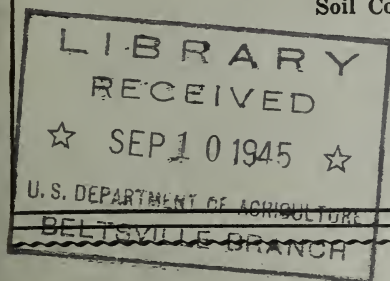
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Three Introduced Lovegrasses for Soil Conservation

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Soil Conservation Service



UNITED STATES DEPARTMENT OF AGRICULTURE

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PREFACE

This publication on three recently introduced grasses contributes directly to the wartime food production program and postwar period of adjustment as well as to agriculture generally.

These lovegrasses are important acquisitions to the farm and range. Their efficiency in controlling wind and water erosion and in improving soil structure under adverse soil and climatic conditions makes them exceptionally valuable for soil and moisture conservation. As such, they increase proportionately the capacity of the lands they occupy and associated lands for crop production. At the same time, their ability to increase the carrying capacity and lengthen the grazing season of pastures and ranges is an outstanding asset in the direct increase of livestock and dairy production.

The unusual qualities of these grasses make them particularly suited for the reclamation of lands that have been damaged and scarred by war activities, for the more profitable utilization of farm lands that are subject to retirement from cultivation, for the extension of agriculture in sections where the rainfall is low and irrigation water is limited, and for the revegetation and renewed use of depleted range lands.

The information contained in this publication will be found helpful not only to technicians engaged in agricultural work but to farmers and ranchers. It is generally applicable to the southern half of the United States and to special conditions farther north.



Three Introduced Lovegrasses for Soil Conservation

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¹ The writer is indebted to many farmer cooperators and State and Federal workers for much of the information presented here and expresses grateful appreciation for this valuable assistance.

INTRODUCTION

The lovegrasses compose about 250 species with indigenous representatives occurring in all the temperate regions of the world (5).² Although a very large group, in general the species of *Eragrostis* have not been recognized as of much agricultural importance in the United States. Judged solely from the standpoint of forage value in comparison with the leading and better known pasture and hay grasses, this view may be justified. However, when evaluated upon the broader basis of usefulness for soil and moisture conservation combined with crop and livestock production values, some of the more recently tested lovegrasses appear to have a definite place in the agriculture of many parts of the country. Particularly do they merit consideration during the present War emergency period because of qualities which enable them to produce quick, effective results. Three species that fall in this category are weeping lovegrass (*Eragrostis curvula* Schrad Nees), Boer lovegrass (*E. chlorelas* Steud.), and Lehmann lovegrass (*E. lehmanniana* Nees).³

HISTORY OF INTRODUCTION OF THE GRASSES

These three grasses are indigenous to South and East Africa, where they are said to vary greatly in vegetative characteristics. Various forms have been introduced by the United States Department of Agriculture from time to time without having attracted special attention. The accessions with which this publication is concerned are distinctive in that they appear to represent outstanding geographical strains that remain true to type wherever planted.

The weeping lovegrass accession was obtained through H. N. Vinall of the Bureau of Plant Industry in 1928. It was from a collection made in Tanganyika by L. W. Kephart and R. L. Piemeisel in 1927 while on an expedition for the Bureau of Plant Industry to collect promising grasses and legumes in East Africa. The Boer and Lehmann lovegrasses were obtained through Dr. M. Wilman, Director of the McGregor Museum, Kimberley, Union of South Africa, in 1932. Seeds of all three grasses were received by the writer while he was Director of the Boyce Thompson Southwestern Arboretum at Superior, Ariz.

Planted in separate lots on the arboretum grounds, the grasses made good growth and produced mature seed crops the first year. In turn, samples of this seed were made available to the Division of Plant Exploration and Introduction of the Bureau of Plant Industry, with which the writer was affiliated as collaborator.

Subsequently, in 1934, while the writer was in charge of the Southwestern Station, Erosion Plant Studies in the Division of Plant Exploration and Introduction, he received from that Division a collection of seeds containing these grasses. Shortly thereafter, the growing and testing of plants for erosion control became a function

² Italic numbers in parentheses refer to Literature Cited, p. 89.

³ According to J. R. Swallen, associate botanist, Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture, the type specimens are not available for comparison and the identifications are therefore subject to review and confirmation.

of the Nursery Division of the Soil Conservation Service to which, in the meantime, the writer had been transferred. Accordingly, as a part of a general cooperative plant material study and production program, organized observational tests were initiated by the writer at the Soil Conservation Service nursery at Tucson, Ariz., in 1935 to determine the relative value of these grasses for soil conservation.

Of the many lovegrasses under observation at that plant-testing center, the aforementioned accessions were selected as showing superior qualities and as worthy of more extended trials. Under the Soil Conservation Service accession numbers A-67—weeping lovegrass (*Eragrostis curvula*), A-84—Boer lovegrass (*E. chlorome-las*), and A-68—Lehmann lovegrass (*E. lehmanniana*) were distributed widely for testing at other locations. Seed produced at the Tucson nursery was made available to other plant-testing centers of the Soil Conservation Service and to field stations of the Bureau of Plant Industry, as well as to a number of the State agricultural experiment stations.

NATIVE HABITAT CONDITIONS

Climate and Topography in Relation to Distribution and Use

According to Rogers (35), the main physical features of South Africa include (1) a pronounced semicircular escarpment located at varying distances from the coastline and characterized by broken, rugged mountains up to 10,000 feet on the eastern side, (2) an extremely diversified territory lying between the escarpment and the oceans, and (3) a great interior plateau ranging in elevation from 3,000 to 6,000 feet.

The topography of East Africa is strikingly similar to that of South Africa except that the mountains rising from the central plateau are much higher, with isolated peaks 14,000 to 19,720 (Mt. Kilimanjaro) feet in elevation that remain snow-clad the year around.

The average annual rainfall of South Africa as reported by Cox (11) and Evans (18) ranges from 50 inches annually in eastern Natal and parts of the Transvaal to less than 5 inches along the west coast. For most of the country, summer is the season of greatest rainfall, but at the southwestern extremity of the subcontinent there is a belt of winter rainfall. The mean annual temperature is remarkably uniform, but the seasonal and daily ranges are for the most part extremely variable.

According to Reed (34) and Shantz and Marbut (37), the rainfall of East Africa ranges from about 20 to more than 50 inches annually, depending on the elevation. The temperature, like the rainfall, varies with altitude but in general the climate is equable. Except for the mountainous districts, freezing temperatures are rare.

The significance of this diversity of native-habitat conditions is seen in the fact that all three of these lovegrasses are distributed practically throughout this entire country (except that Boer and Lehmann lovegrasses are not known to have been reported from East Africa) under almost every conceivable condition of soil, moisture, and exposure. In South Africa, as reported by Phillips (33), and Garabedian (20), Bews (2, 3, 4) and Evans (17), one or more of

them are found in the heavy-rainfall belts of the East, the high Drakensberg Mountains, the extensive inland-plateau regions, the winter-rainfall and the dry Karroo districts of the Cape Province, as well as the extremely low rainfall sections of the West. In the very arid regions, however, they are usually confined to swales and the borders of intermittent water courses where there is an extra accumulation of soil moisture.

Environment in Regions of Collection

According to Kephart and Piemeisel,⁴ the weeping lovegrass accession was collected near the top of the escarpment, between Mbulu and Ngorongoro Crater in north central Tanganyika, where it occurred in almost solid stands. This part of Tanganyika is roughly undulating and ranges in elevation from 4,000 to 6,000 feet. While the soils are composed chiefly of deep red loams with occasional patches of sand, this lovegrass was found growing on "an area of black, waxy, sun-cracked soil." Owing to the high altitude, the climate is comparatively cool, and mists and cold winds are common during the greater part of the year. While the temperature frequently drops to the low forties, actual frost seldom occurs. The average annual rainfall ranges from 25 to 35 inches with two drought periods, one lasting about 2 months and the other of 4 to 5 months duration.

As described by Rogers (35) and Evans (17), the topography, soils, and rainfall vary greatly in the Griqualand West region of South Africa, where the Boer and Lehmann lovegrass accessions were collected and where weeping lovegrass also occurs. The eastern portion of this region consists of open valleys with deep alluvial soils and gravels. The central area, characterized by the presence of numerous depressions, dolomite outcrops, and the lack of live water-courses, is composed mainly of shallow limestone soils interspersed with stretches of red sands overlying calcareous formations. The western portion is an undulating area composed largely of sandy plains, low-lying rounded hills and dry river valleys.

The climate of this region is predominantly dry, with hot summers, frosty winters, and an erratic rainfall of 12 to 20 inches falling mostly (75 to 80 per cent) in summer as thunderstorms. The humidity generally is low, and prolonged droughts are not uncommon. According to Reed (34), the average annual precipitation at Kimberley for a period of 41 years was 15.86 inches, with a maximum temperature of 107° F. and a minimum of 21° for a period of 31 years. The frost period in this locality lasts from 100 to 150 days.

Although all three lovegrasses grow naturally in Griqualand West, Lehmann lovegrass plays the dominant role. Evans (17) speaks of it as a leading component of a luxuriant growth of native grass seen after rain in the sandy belts (fig. 1).

The Place of These Lovegrasses in Ecological Succession

According to Bews (1, 2, 3, 4), the three lovegrasses under discussion, along with most other species of this genus, are considered as

⁴From the unpublished report of the East African Expedition, U. S. Department of Agriculture, 1927-28.



FIGURE 1.—Lehmann lovegrass in native habitat on Kaap Plateau west of Kimberley in South Africa. The woody plant association is mainly wild olive (*Olea verrucosa*) and Vaalbos (*Tarconanthus minor*). (Courtesy of J. P. H. Jacobs, Dohne Research Station, Cape Province, Dohne, Union of South Africa.)

belonging to the earlier or pioneering stages of grassland succession. The part they play in the development and maintenance of economic grassland depends greatly upon the location, climatic conditions and the treatment of the grass formation. Over much of the grasslands proper of South and East Africa, redgrass (*Themeda triandra* Forsk) is the leading climax species with the lovegrasses occupying an initial, intermediate or even dominant place in the composition, depending upon local conditions. In the eastern or more moist grassland regions, according to Shantz and Marbut (37), the stages of succession after breaking are much as on our High Plains: first, a weed stage (dominated by *Tagetes minuta*); second, a short-lived perennial stage (*Gnaphalium*); third, a short-lived grass stage (*Cynodon incompletus*); fourth, a long-lived grass stage (*Eragrostis curvula*) and other grasses; and a final stage (*Themeda triandra*). This analysis is in keeping with Bews (3), who states that there are many local variations with the earlier stages of the succession often lacking and the lovegrasses assuming the complete primary role.

As discussed further by Bews (3, 4), the grasslands of the whole western side of South Africa are closely similar to the initial stages of the succession of the eastern grasslands. In the higher rainfall regions of the East, the lovegrasses serve as very important grasses in the initial stages of grassland development. At the same time, along with similar widely adapted drought-resistant species, they become dominant in the climax stages of the semiopen grasslands of the drier West.

Another and very significant condition under which the lovegrasses assume a dominant role is that of "Changed Veld," as termed by Bews (3), in which the climax grasses have been destroyed by such

artificial agencies as burning, grading, and soil erosion. Here species such as weeping lovegrass, Boer lovegrass, Lehmann lovegrass, *Sporobolus indicus*, and *Cynodon dactylon* which, under undisturbed high-rainfall conditions are somewhat suppressed, often become dominant and persist for a long time. This logical sequence is due largely to the fact that these light-demanding grasses, unlike the more succulent climax types, possess qualities which enable them to become established without the protective cover of other vegetation. In discussing this question, Bews (3) stresses the importance of grasses of this type as an aid to eastern grassland development, owing to the fact that the climax types are unable to colonize bare areas by themselves.

Recognized Erosion Control Qualities in South Africa

These lovegrasses are recognized in South Africa as having qualities which recommend them for erosion control. While they have not been utilized to any great extent in artificial revegetation, as early as 1918 Bews (3) advised farmers against burning these and similar grasses "because being deep-rooted species, they help to bind the soil and prevent soil erosion." In discussing the changed soil and moisture conditions brought about by erosion, he concluded that where the soil has become dried out by severe gullyling only drought-resistant grasses such as the love grasses are able to survive. He considers their presence of prime importance in the beginning stage of the gully-curing process. The soil-conserving qualities of grasses of this type are pointed out by him as further evidenced by their ability to become established readily under adverse bare-ground conditions.

Recognized Forage Values in South Africa

According to the best available information, in South Africa weeping, Boer, and Lehmann lovegrasses are utilized mainly for natural pasture. No attention has been given to their cultivation. In comparison with the more luscious species, they are considered of secondary importance as fodder crops, more especially in the eastern grasslands. However, their value for grazing purposes appears to depend very much upon local conditions. In the higher rainfall areas of the East, where the softer grasses are more abundant, their greatest use occurs under "Changed Veld" conditions—that is, where the climax species have been destroyed. On the other hand, throughout the drier western side of the subcontinent they form an important constituent of native pasture land, embracing parts of the Orange Free State, Griqualand West, Karroo, Kalahari, and Namaqualand.

Like most of our more common grasses, these lovegrasses are said to remain palatable for grazing up to the flowering stage, after which time the growth becomes somewhat coarse and tough and consequently unpalatable.

Evans (17) lists *Eragrostis curvula* var. *valida* among the pasture grasses occurring in the Eastern Grass Veld and names *Eragrostis lehmanniana* as one of the principal pasture and hay grasses in the Griqualand West region. Garabedian (20) describes *Eragrostis curvula* as a "valuable pasture grass" and Phillips (33) says that *Era-*

grostis chloromelas is a "grass very much liked by cattle." Notes on the grazing qualities of *Eragrostis curvula* compiled from various localities by the National Herbarium of Pretoria, Union of South Africa, and obtained through official correspondence with J. J. B. Acocks, Divisional Ecologist, Dohne Research Station, Cape Province, Union of South Africa, refer to it as a "useful pasture grass in its early stages" and "a quick grower of which cattle are very fond."

A review of Henrici's (23) grazing studies with sheep under the natural grassland conditions of the Fauresmith District of the Orange Free State shows weeping lovegrass, Boer lovegrass, and Lehmann lovegrass to have about the same relative palatability rating as the other good grasses of that locality.

MAJOR CHARACTERISTICS

As previously indicated, although the vegetative characteristics of weeping, Boer, and Lehmann lovegrasses are said to be quite variable in their native habitat, these grasses have remained remarkably uniform here. This doubtless is due both to self-fertility and the fact that the original collections apparently were made from more or less isolated plant colonies.

Weeping Lovegrass

Weeping lovegrass is a long-lived perennial bunchgrass, individual specimens of which develop into very large, dense clumps (figs. 2 and 3). Growth is rapid, and stooling begins within 4 to 6 weeks after planting. The new vegetative culms multiply rapidly and continuously throughout the growing season. Under favorable conditions, several hundred closely packed culms form on the crown the first year. Figure 3 shows in cross section the basal culm development of a 3-year-old plant. The new culms originate just below the surface of the ground and from within the crown (fig. 3) which, together with their closely packed, deeply rooted character serves to protect the plant against destructive agencies such as erosion, cold, drought, blowing sands, and burning.

As the plant becomes older, offsets commonly form at the nodes for some distance up the stems. During periods of warm, rainy weather these offsets frequently send out aerial roots and establish themselves as new plants in the debris around the crown of the mother plant, becoming detached either before or after establishment. Under favorable conditions, they were found to transplant about as readily as young seedlings or divisions from old plants.

The basal leaves are long (24 to 48 inches), slender, and as the species name implies, characteristically curving (fig. 4). They taper to very fine, hairlike brownish threads which often tangle with those of neighboring plants. Noticeably purplish at the base while young, they are generally light green through the succeeding growing season, changing to greyish brown or a reddish shade and becoming somewhat dry and tough in the fall and during severe droughts, but remaining green and comparatively soft at the base and in a non-dormant condition all winter in the warmer sections. Since the leaves



FIGURE 2.—Individual 2-year-old plant of weeping lovegrass at seeding stage, showing characteristic growth habit. National Observational Nursery, Beltsville Research Center, Beltsville, Md.

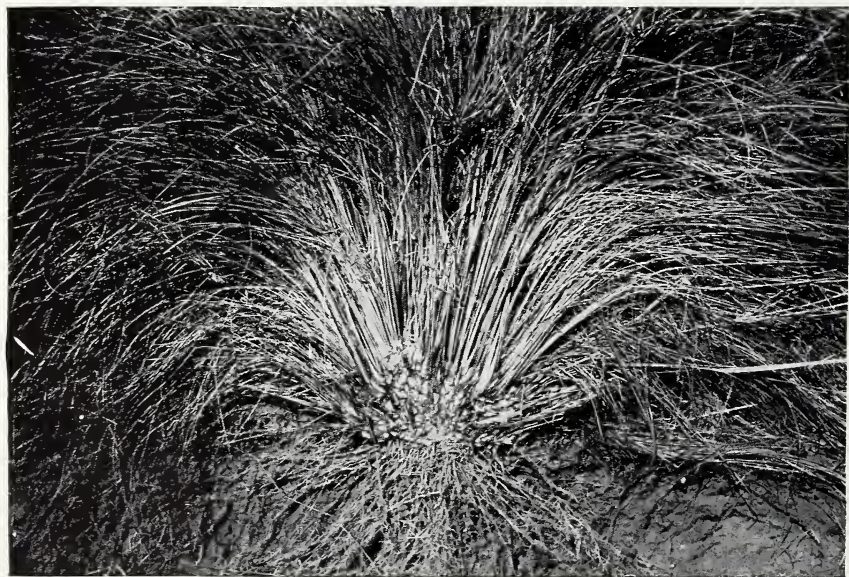


FIGURE 3.—Cross section of the crown of a 3-year-old weeping lovegrass plant, showing the numerous and closely packed basal vegetative culms that furnish extra protection against erosion, cold, drought and fire, and the accumulated leaf growth.



FIGURE 4.—Field of weeping lovegrass 90 days after planting, showing characteristic curved leaf growth and complete, erosion-resistant ground cover from 3-foot row spacing. The seeding rate was 1 pound per acre.

are numerous, closely crowded, and mainly basal, with a new crop produced during each successive growing season, thick masses of vegetative material soon build up around the crowns of undisturbed plants. (See figures 2 and 3.) The leaves on the upper part of the stems are comparatively short and unnoticeable.

The seedstalks develop early in the season as compared to most grasses and grow rapidly, normally attaining a height of 4 to 5 feet. They are erect to somewhat spreading in habit, but the flower heads are drooping, which gives the plant a generally pendulous appearance. (See fig. 2.) During the flowering stage the grass emits a distinctive, pleasing odor. The seed heads are large (8 to 12 inches long) and open and usually carry from 300 to more than 1,000 seeds, many of which become exposed to view upon ripening. The seeds (caryopses) are small, oval, translucent, brownish, and with a black eye (embryo) (fig. 5).

As observed by repeated field excavations and by growing seedlings in containers provided with glass fronts, as employed by Crider (12, 13), the root system of weeping lovegrass consists of many uniformly large, deeply penetrating roots of approximately the same size throughout. Unlike the roots of most grasses, they appear to remain more or less permanently intact but shed their outer covering before they are a year old.

The primary roots complete their function of seedling establishment in about 3 to 4 weeks after the seed sprouts when, coinciding closely with the beginning of vegetative culm development, the permanent main roots start forming. The first ones to form grow almost straight down, with those subsequently produced progressively widen-

ing the angle and utilizing the unoccupied soil. Originating from these larger roots are numerous fine, minutely branched rootlets that develop progressively about 2 inches behind the growing point on tissue about 48 hours old. Coming out at right angles and occurring at the rate of 30 to 60 per inch along the main roots, they eventually almost completely fill the remaining soil interstices.

Like the top growth, the root growth is rapid. During the first month after planting, the main roots were found to elongate at an average rate of 0.54 of an inch in 24 hours (fig. 6), with a maximum daily growth of 2 inches.

Figure 7 shows the complete root system of two weeping lovegrass seedlings at the age of 4 months, washed free of soil, as grown in a 4-inch (width) by 20-inch (length) by 48-inch (depth) glass-front box. The soil was placed in the box in approximately the same order that existed under field conditions to a depth of 48 inches. The first 12 to 18 inches was composed of loamy sand and the remainder heavy silt loam passing into sandy clay in the proportion of 73 percent sand, 17 percent silt, and 10 percent clay. The pH of the soil averaged 5.5 and did not vary appreciably from surface to subsoil. A high percentage of the roots grew more than 4 feet and formed a dense mass to a depth of over 2 feet. As grown in the field, 2-year-old plants were found to contain 600 to 800 main roots, with a maximum depth of more than 6 feet and a maximum lateral spread of more than 10 feet.

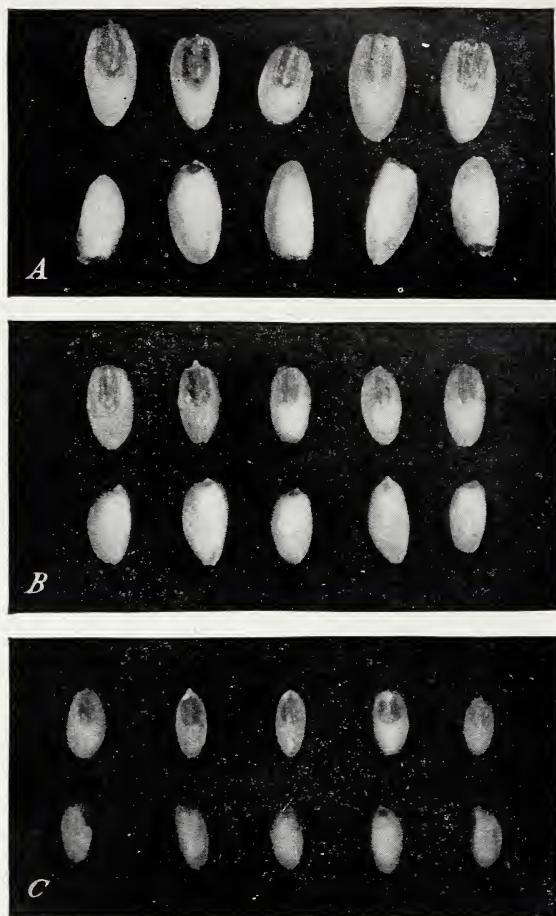


FIGURE 5.—Seeds of: A, Weeping lovegrass; B, Boer lovegrass; C, Lehmann lovegrass; magnified 12 times.

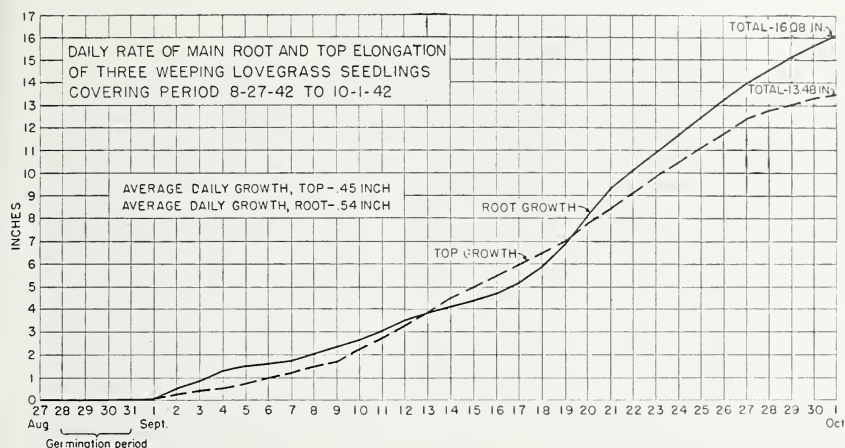


FIGURE 6.—Comparative growth rate of the roots and tops of weeping lovegrass during the first 35 days after planting.

Boer Lovegrass

Boer lovegrass also is a long-lived, perennial bunchgrass (fig. 8, 14). It makes rapid growth, starts stooling early, forms dense clumps, and for a given period produces about one-third fewer vegetative culms than weeping lovegrass.

The basal leaves, which constitute the bulk of the foliage, are rather long (24 to 36 inches), narrow, slightly rough to the touch, flexible, curving and characteristically bluish in color. Being very abundant, closely crowded, and persistent, they likewise produce in a short time heavy masses of vegetative material around the crowns of unmolested plants. Where it is not too cold, the lower part of the leaves remains green and nondormant over winter; but in general the foliage dries out and, like some of our good winter-grazing native grasses, becomes somewhat curly and cures on the plant.

The seed stalks are distinctly erect, stout, and normally about 3 to 3½ feet tall. The seed heads are of medium size (8 to 10 inches long), open, pyramidal in shape, and stiffly erect. The seeds (caryopses) are similar in shape and color to those of weeping lovegrass but about half their size. (See fig. 6.)

This species has a root system very similar to that of weeping lovegrass, the roots being deep, wide-spreading, and well distributed. Likewise, the main roots are practically the same size throughout and possess numerous, fine, minutely branched rootlets.

Lehmann Lovegrass

This is a perennial grass, but, unlike the two preceding bunchgrasses, the stems are commonly prostrate and take root and produce new plants at the nodes. The stems are slender, smooth, flexible, and from 18 to 36 inches long. While they are fewer in number as they emerge from the crown than in the case of the other two lovegrasses, this is counterbalanced by early and profuse branching and rapid new plant development by layering. The leaves are short (3 to 6

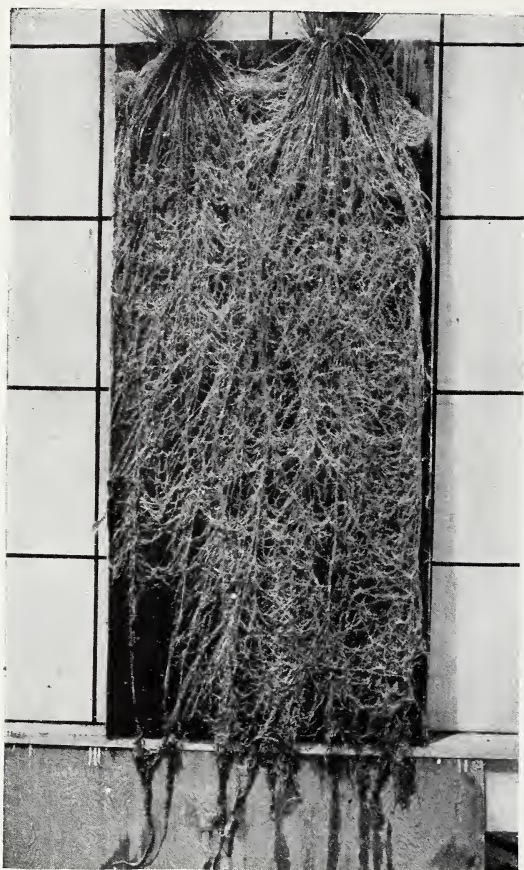


FIGURE 7.—The complete root system (washed free of soil) of two weeping lovegrass seedlings at the age of 4 months, as grown in a 4-inch (width) by 20-inch (length) by 48-inch (depth) glass-front box. The backdrop is laid off in 1-foot squares.

inches), dark green, smooth, and narrow, tapering to a fine straight point. Growth is rapid and the stems, although not as leafy as weeping or Boer lovegrass, are very abundant. Within a short time after planting, a thick mass of layered (if moisture conditions are favorable) vegetative material is produced, normally about 3 feet across (fig. 8, *B*).

The seedstalks are characteristically numerous and normally attain an average height of about 2 feet, presenting a greyish mass while in the flowering and fruiting stages. The seed heads are comparatively small (3 to 6 inches long) and open. The seeds (caryopses) also are similar in shape and color to those of weeping lovegrass, but about one-fourth the size. (See fig. 5.)

The root system of Lehmann lovegrass is about as dissimilar to that of the other two lovegrasses as the

above-ground parts. This grass is less deeply rooted and the main roots are more branched and fibrous. Also, they are characteristically dark in color.

Although under favorable conditions all three grasses come up quickly, develop rapidly, self-seed readily and, in the warmer sections, persist in remaining partly green during winter, they nevertheless may be killed out easily by cultivation. They are remarkably free from disease and insect attack, the only observed occurrence of either being a minor smut (*Ustilago spermophora* B. & C.)⁵ found on weeping lovegrass in the State of Maryland.

⁵ Identified by C. L. Lefebvre, Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering.



FIGURE 8.—A, Typical Beer lovegrass in initial observational plot at the Soil Conservation Service nursery at Tucson, Ariz.; B, characteristic growth of Lehmann lovegrass in initial observational plot.

CLIMATIC AND SOIL ADAPTATIONS

Rainfall Requirements and Drought Resistance

Weeping, Boer, and Lehmann lovegrasses are primarily summer-rainfall grasses. All three are drought-resistant but respond to favorable soil moisture. They differ considerably, however, in individual rainfall requirements. Planting tests show that weeping lovegrass may not be expected to become permanently established where the average annual rainfall is less than 15 inches, with 6 to 8 inches in summer. On the other hand, there is abundant evidence that Boer and Lehmann lovegrasses may be grown with as little as 10 to 12 inches of rain, with 4 to 6 inches in summer. It is apparent that Lehmann lovegrass can be established with less rainfall during the early seedling stage than Boer lovegrass, but the latter has proved more drought-enduring when once established. Both appear exceptionally well adapted to the dry climate of our Southwest.

The amount of rainfall necessary to produce a good crop of any one of these lovegrasses, however, is influenced greatly by local conditions, including especially the water-holding capacity of the soil, degree of erosion, and whether or not soil and moisture-conserving practices are followed. The question of rainfall distribution is also of prime importance, for in order to be most effective, rain must occur during the season when it can be fully utilized in promoting growth and seed production. In areas of borderline rainfall adaptation, stand failures have been observed to have resulted less from a shortage in the total annual precipitation, than from the failure of rain to come when most needed.

In critical rainfall areas occasional prolonged droughts may be expected to kill out well-established stands of these grasses; but normally, as reported to obtain in their native habitat, if the grasses have made good seed crops, the stands are renewed by natural self-seeding when moisture conditions are again favorable. This has been observed to occur in the Southwest with Lehmann lovegrass in particular, the new stand in some instances exceeding in density that of the original.

Evidence of the relative ability of these lovegrasses to survive and perpetuate themselves under severe moisture stress was pronounced during a prolonged drought in southern Arizona in 1942-43. Their response to the dry spell was typified by its effect upon trial plantings near Continental. The average annual rainfall at this location is 10.03 inches, with 5.32 inches in summer, but during this 16-month drought period only 5.83 inches of rain fell, with 3.48 inches in summer. Established during favorable moisture conditions in 1938 and 1940, all three grasses continued satisfactorily until the occurrence of the dry spell at the end of which the original stand of Boer lovegrass was found to have survived practically 100 percent and that of weeping and Lehmann lovegrasses to have been killed out. However, on the resumption of normal rainfall the succeeding summer, the stand of Lehmann lovegrass was restored by self-seeding. The conditions apparently were too severe for the restoration of the weeping lovegrass.

Temperature Requirements

Weeping lovegrass is by far the most cold-resistant of these grasses, having been found to succeed as far north as central New York State in the eastern half of the United States and northern Oklahoma and New Mexico in the West.

Undisturbed, first-year plantings of weeping lovegrass at Beltsville, Md., have been uninjured by winter temperatures of -14° to -16° F., and well established plantings have withstood temperatures as low as -20° near Deansboro, N. Y., and -17° in the vicinities of Fayetteville, Ark., Dalhart, Tex., and Shiprock, N. Mex. Seedlings are known to have been killed during very severe winters at Manhattan, Kans., Woodward, Okla., Cheyenne Wells, Colo., and other points near the minimum temperature range of this grass. Usually, however, if the stand is reduced by winter-killing, it will become restored by volunteering (fig. 9).

Boer lovegrass is considerably less cold-resistant than weeping lovegrass. For example, at Beltsville, Md., where weeping lovegrass was uninjured by -16° F., Boer lovegrass failed to survive. It was killed out completely at the Pullman, Wash., nursery and during severe winters at Woodward, Okla. At the Albuquerque, N. Mex., nursery, however, with winter temperatures only a little higher, it has never been injured by cold. A 1-year-old range planting at the New Mexico Agricultural Experiment Station, Las Cruces, N. Mex., was uninjured by -6° .



FIGURE 9.—Two generations of self-seeded weeping lovegrass on untill sandy loam at Beltsville, Md. The larger plants are volunteers from nearby older plants; the smaller plants came up in the spring from seed produced by the volunteers the preceding year.



FIGURE 10.—Second-year weeping lovegrass at Beltsville, Md., showing winter-killing induced by early fall mowing. The first row at the left, mowed September 21, and the second row, mowed October 28, were killed the succeeding winter (minimum temperature, -16° F.) whereas, the third row, mowed November 28, with the hay left as mulch, and also the rest of the unmowed field were uninjured.

Lehmann lovegrass is the least winter-hardy. Remarkably quick maturing and self-seeding readily, it will grow as an annual much beyond its normal minimum temperature range but will not succeed permanently as a perennial where the temperature gets as low as zero. It was killed out badly at the Dry Land Agriculture Field Station, Tucumcari, and the Albuquerque, N. Mex., nursery at temperatures around -3° and winter-killed completely at the Southern Great Plains Field Station, Woodward, Okla., at zero and -5° .

It has become increasingly evident that winter injury cannot be attributed to low temperatures alone and that local conditions, such as soil moisture and texture, atmospheric humidity, amount of snow cover, age and degree of dormancy of the plant, also have a definite influence upon survival. As in the case of most perennial crop plants, and more particularly on account of the tendency of these grasses toward nondormancy during winter, they appear to be subject to greater winter injury as the northern limit of their adaptation range is approached if encouraged by irrigation or other means to remain in succulent condition until cold weather. At the same time, it has been observed that they are less resistant to low temperatures if inadequately supplied with moisture during the colder part of the winter. The influence of soil texture was strikingly evident at the Pullman, Wash., and Elsberry, Mo., nurseries where, on heavy soils, weeping lovegrass was injured severely by heaving.

In field trials at the National Observational Nursery at Beltsville, cutting back weeping lovegrass during early fall was found to have a marked effect in causing winter killing. The portion of

a first-year planting that had been mowed on September 21 and again on October 28, as well as the portion that had been mowed only on October 28, before the plants had become adjusted to the seasonal change, were killed out completely during the succeeding winter (minimum temperature, -16° F.). On the other hand, an immediately adjacent part of the same planting that was not mowed until November 30, and an unmowed area, showed no injury (fig. 10).

Although the temperature relationships of these grasses have not been finally determined, analyses of available data on their response to country-wide conditions have made it possible to establish as their approximately safe minimum temperature range, the following: Weeping lovegrass, -10° F.; Boer lovegrass, -5° ; Lehmann lovegrass, $+5^{\circ}$; or, interpreted in terms of average annual minimum temperature, as given by Kincer (26), -5° , $+10^{\circ}$, and $+15^{\circ}$, respectively.

In no instance have they been observed to be affected adversely by hot weather alone. Also, they seem not to be influenced materially in growth habit by the degree of atmospheric humidity to which they are subjected, except that a combination of prolonged high humidity and high temperature appears to lessen seed production of weeping lovegrass.

Soils and Sites

Country-wide observations show that these grasses will grow on soils varying in texture from coarse sand to heavy silts and clays, differing in P_h reaction from strongly alkaline to highly acid, and ranging in fertility level from very poor to fertile. Their outstanding soil-adaptation quality, however, is the ability to become established on "poor land" which, although varying in interpretation, is nevertheless generally understood to mean the lowest class soils for the particular section involved.

Although all three species possess the unique quality of growing on bare, impoverished lands, they nevertheless produce proportionately greater foliage and seed yields, retain their normal color and succulence longer and produce more palatable forage on more fertile soils. Tolerant of acid situations, as strikingly indicated by their good growth generally in the East, they also respond favorably to soils containing considerable lime as exemplified best in the Southwest, where they do particularly well on the more or less highly alkaline-calcareous soils of that region. In general, they seem to prefer soils of lighter texture and do best on relatively fertile sandy and silt loams.

These grasses are sun-loving and do well in the open ground; yet as in the regions of their collection, they associate readily with shrub and tree growth, especially in the less densely wooded areas of the semiarid Southwest. (See figs. 1 and 12, *B.*) Weeping lovegrass also has been observed to make good growth in partial shade in the East, notably at the edge of woods, in woods pastures and in orchards. In tests at Beltsville to determine the value of this grass as ground cover in shady situations, it was found to make excellent growth and protective cover in almost complete shade where Bermuda grass was a

failure. Other conditions being favorable, the only retarding influence of partial shade that has been observed was lessened seed production. All three species have in common the quality of intolerance to standing water.

General Distribution and Adaptation Range

Based upon the results of country-wide plantings and the average annual minimum temperature and precipitation compilations of Kincer (26), it has been possible to delineate with reasonable accuracy the general areas within the United States where, under conditions that obtain naturally, these lovegrasses may be expected to succeed.

It is apparent that weeping lovegrass is adapted to almost the entire southern half of the country. The northern limit of its adaptation range in the East begins in southern New England and extends southwestward to include the Ohio River Valley. Continuing, it passes southwesterly through southern Missouri, northern Oklahoma and Texas, and westward through northern New Mexico, Arizona and southern Nevada. In western Texas and New Mexico and in Arizona and Nevada its normal adaptation range is confined mainly by low rainfall to comparatively small, disassociated, favorably situated areas. For like reason, in the Pacific Coast States it is confined principally to the higher rainfall and fog areas of the coastal belt. On account of the adverse influence of combined high humidity and high temperature on seed production, it appears not to be adapted to southern Florida.

Boer lovegrass has a somewhat more limited range than weeping lovegrass. The northern limit of its adaptation range in the East begins in southern Maryland and extends southwestward below the Appalachian Range, westward through southern Arkansas, southwestward through central Texas, northwestward into central New Mexico, westward through central Arizona and southern Nevada, and northerly through the coastal belt of the Pacific Coast States. Because of its extreme drought resistance, it appears particularly well adapted to the dry, warmer parts of the Southwest.

The fact that Lehmann lovegrass is the most sensitive to cold of the three kinds is reflected in its adaptation range. Beginning in the East in the southern part of Virginia, the northern limit of its adaptation range extends southwestward to include the Atlantic and Gulf Coastal Plains and foothills, northwestward to include the lower Rio Grande and Pecos River Valleys and contiguous foothills, and westward and northwestward through southern New Mexico and Arizona. Like Boer lovegrass, it appears especially well adapted to the drier, warmer parts of the Southwest. Also, it appears well suited to much of the Pacific coastal belt.

It should be understood that there are local situations within their generally delineated adaptation range where these grasses may not be expected to grow, such as high, cold mountains and extremely desert situations. Likewise, there are many areas outside of these limits where they will succeed, such as the sand-dune area around Lake Michigan where weeping lovegrass had been found to do well.

Also, in the semidesert sections of the Southwest as pointed out by Flory and Marshall (19) for weeping lovegrass, and in the Pacific Coast States the growing range of all three species may be extended where extra moisture can be made available—that is, under irrigation and on areas which receive natural flooding or where water is retained or spread by means of conservation devices such as check dams, diversion ditches, and contour furrows.

Ordinarily, these grasses may be expected to succeed naturally only where there is ample summer rainfall for normal growth, which would seem to preclude their use in the winter-rainfall belt of California. However, apparently owing to their habits of nondormancy, rapid maturity, and drought resistance they have been found to do well in that section, more particularly in the areas that are influenced directly in temperature and humidity by proximity to the ocean.

SOIL CONSERVATION USES

Some of the more determinative qualities which contribute to the usefulness of these grasses for soil conservation are: (1) Adaptability to many and varied soils, particularly the poorer classes; (2) easy and quick establishment under adverse conditions; (3) rapidity of growth and maturity during critical periods; (4) production of thick masses of vegetative soil cover; (5) voluminous, tenacious, and deeply penetrating root systems; (6) resistance to destructive agencies such as blowing sands, floods, fire, weed competition, and decay; (7) habits of ready selfseeding; (8) heavy yields of viable seeds; (9) adaptation to simple methods of culture; and (10) ease of eradication when circumstances warrant.

General Ground Cover and Revegetation

Evidence is abundant that the inherent pioneering habit of these grasses has been retained and given practical expression in revegetation operations here, enabling them to become established, produce good ground cover, and perpetuate themselves under environmental conditions that, in the case of many other species, cause stand failure. They have as perhaps their greatest asset that of providing quick vegetative cover on poor, eroded soils. Their usefulness for this purpose has been found to have very wide application, embracing abandoned and retired farm lands, depleted and denuded range areas, inland and waterfront sand barrens, burnt-over lands, and innumerable local areas in good agricultural districts that have become impoverished or bare through soil erosion or other cause.

Plantings of weeping lovegrass that have demonstrated the value of this grass for revegetation and soil stabilization under severe wind erosion drought conditions include many in the Southern Great Plains and environs, both on public and private lands. Some loss of stands from winter-drought injury has occurred in the more critical borderline areas of adaptation, such as western Kansas and eastern Colorado, but even here the lovegrass in mixture seedings was found to serve a useful purpose in producing quick erosion-resistant soil cover and protection to the slower-growing native



FIGURE 11.—Weeping lovegrass as an erosion-control, seed-production grazing crop on land considered too badly eroded and impoverished for ordinary row-crop farming. As shown, near close of third growing season and 6 weeks after mowing, the new recovery growth was 10 to 12 inches high. It analyzed 10.31 percent protein, and was being grazed readily by Jersey cattle, Northwest Louisiana Land Utilization Project, Minden, La.

species until they become established. In comparison with most grasses under wind-erosion conditions in the Southern Great Plains, it is superior in seedling vigor, ease of establishment, forage production, and natural self-seeding ability (fig. 9).⁶

The effectiveness of weeping lovegrass in providing quick ground cover and controlling sheet and gully erosion on abandoned and retired crop lands has been demonstrated best perhaps on land utilization projects. Typically successful field-scale plantings are located on the former Cookson Hills project, Muskogee, Okla., the Northwest Arkansas project, Fayetteville, Ark., and the Northwest Louisiana project, Minden, La. (fig. 11). These plantings are on lands that had been farmed for many years previously and had become too badly eroded and impoverished to be used further for row-crop farming common to the respective communities. By the use of simple cultural methods the weeping lovegrass was easily and successfully established, and completely controlled erosion the first season.

Boer and Lehmann lovegrasses, largely because of their ability to become established and perpetuate themselves under very low rainfall conditions, have been found especially suitable for general ground-cover and revegetation uses on range lands in the Southwest. The cooperative investigations by Bridges (8) did much to substantiate earlier observations by the Soil Conservation Service as to the value of these two grasses for reseeding depleted range lands.

⁶ From unpublished reports by D. A. Savage, senior agronomist, Bureau of Plant Industry, Soils, and Agricultural Engineering and James E. Smith, manager, Soil Conservation Service nursery, Woodward, Okla.

Bridges' trial seedlings were located on an area of the experimental range tract of the New Mexico Agricultural Experiment Station near Las Cruces, which, composed generally of light, shallow soils and having an average annual rainfall of only 9.33 inches, represents about the extreme conditions where artificial revegetation may be expected to succeed. This environment served to emphasize the superior qualities of these two lovegrasses for range revegetation as expressed in Bridges' summary, which states that of 121 native and introduced grasses tested during the 6-year period (1935-41) only three gave completely satisfactory results and showed promise of being able to maintain themselves permanently under range conditions at that location. One of these is locally native Rothrock grama (*Bouteloua rothrockii*) and the other two Boer and Lehmann lovegrasses.

Field-scale range revegetation seedlings of Lehmann lovegrass have been made under various adverse site conditions in southern Arizona, southern New Mexico, and western Texas totaling more than 5,000 acres.

One of the first of these plantings to have demonstrated the peculiar adaptability of Lehmann lovegrass for use in general range revegetation was a 100-acre seeding made in 1939 on the C. L. McKinney Ranch, Courtland, Ariz. This planting was a part of the cooperative range conservation program of the Soil Conservation Service. As reported by Tatum,⁷ the area treated was a portion of the ranch that had become severely denuded of good native perennial grasses by a combination of heavy grazing, prolonged droughts, and frequent sheet erosion. A mixture was planted that included Lehmann lovegrass, weeping lovegrass, side-oats grama, Rothrock grama, blue grama, silver bluestem, and cottontop.

The seeding was in narrow strips along widely spaced double contour furrows similar to those shown in figure 12, *A*. Rainfall during the year of establishment and the succeeding 3-year period averaged 14 to 16 inches with a little more than one-half coming in summer. Examination the third year after planting showed that the Lehmann lovegrass, through self seeding and new plant development at the nodes of prostrate stems, had spread from the contour furrows and formed a solid stand of vegetative cover similar to figure 12, *B* over all the acreage that had received occasional runoff water, with scattered seedlings on the remaining higher, drier ground. There was no evidence of any of the other grasses having spread beyond the original stand.

The ability of Lehmann lovegrass to become established and to produce erosion-resistant cover on bare, semidesert range land was even more strikingly demonstrated by revegetation seedlings on the Papago Indian Reservation and the Aravaipa Creek drainage area in southern Arizona. Here, areas that were completely denuded of perennial grasses with the soil sun-baked to a hard crust and subject to severe erosive floods became well covered with this grass within 2 to 3 years after seeding. (See fig. 12, *B*.)

⁷ E. C. Tatum, district conservationist, Southwestern Region, Soil Conservation Service, U. S. Department of Agriculture, Tucson, Ariz.



FIGURE 12.—A, Lehmann lovegrass 5 months after seeding on completely denuded, heavy, flat range land in the Aravaipa Creek drainage area in Arizona. The grass was broadcast over double, widely spaced contour furrows made by a two-toothed subsoiler with shoe attachments. B, 4-year-old range planting of Lehmann lovegrass on the Papago Indian Reservation, in southern Arizona. It spread from contour-furrow seeding similar to that shown in A. Previously, this area was completely denuded of perennial grasses, sun-baked to a dry crust, and subject to erosive floods. The average annual rainfall is approximately 12 inches and atmospheric evaporation about 7 feet.

The success obtained in revegetation practices with Lehmann and Boer lovegrasses under the adverse soil and rainfall conditions of the Southwest are all the more remarkable in view of Griffith's (21) summary to the effect that some 200 species of forage plants, the majority of which had some claim to succeeding in dry situations, previously had been tested without success in southern Arizona.

Burned-over Lands

The favorable results obtained by the U. S. Department of Interior in the use of these lovegrasses for revegetation purposes on Indian lands in southern California indicate that they may have unique value for quickly reestablishing vegetative cover on burned-over lands.

In seeding trials⁸ with 32 carefully selected grasses on burned-over lands on the Pala Indian Reservation, weeping, Boer, and Lehmann lovegrasses were the only species to become established. Based on the phenomenal success of the Lehmann lovegrass, which predominated in thickness of stand and rapid ground coverage, field-scale seedings of this species were made on freshly burned-over chaparral lands on 8 other Indian Reservations in San Diego and Riverside Counties, 300 acres having been planted in December of 1931 and 300 acres in the fall of 1942.

The areas where these seedings were made vary from 500 to 1,800 feet in elevation and the average annual rainfall ranges from 12 to 18 inches with not more than 2 inches during summer. The seed was broadcast at the rate of 1 pound per acre with a whirlwind type of hand seeder without being covered. Establishment was generally satisfactory and the grass has continued as an effective ground cover. Although the permanency of the stand in competition with returning brushy growth remains to be determined, the value of this grass in quickly covering bare, burned-over ground and preventing surface erosion has become clearly evident.

Weeping lovegrass was found to do well at the higher elevations of this chaparral belt, where the rainfall is heavier. Although extended seedings have not been made of Boer lovegrass, it undoubtedly will succeed equally as well and in drier situations.

The success of these lovegrass seedings is significant in view of the fact that the seeded areas lie within the winter-rainfall belt of California which for a period of 4 to 6 months in summer is practically without rain. Apparently, the nondormancy and quick-maturing habits of these grasses make it possible for them to store up an abundance of food reserves during the mild winter and early spring rainy season which, combined with their drought resistance and with favorable atmospheric conditions, enable them to withstand the prolonged dry summer.

⁸ Unpublished report by E. V. Flory, regional chief, Soil and Moisture Conservation Operations, Indian Service, U. S. Department of Interior.



FIGURE 13.—Terrace-outlet channel stabilized by weeping lovegrass transplanted in rows crosswise to the depression at the Soil Conservation Service nursery, Sandy Level, Va.

Drainageways

These lovegrasses have been found well suited for planting in and along drainageways. The qualities which make them useful for this purpose are the same as those which contribute to their usefulness for general ground cover, with emphasis upon (1) ease and simplicity of establishment, (2) rapidity in forming protective cover and (3) tenacious soil-holding capacity. While Boer and Lehmann lovegrasses may be used for watercourse protection within their respective growth ranges, because of its greater vigor and wider adaptation weeping lovegrass appears the most generally suited for this purpose, especially in the higher rainfall areas.

In utilizing weeping lovegrass for vegetating drainageways, the growth habits of the plant are an important consideration, as they may affect both the planting method and the type or design of the channel. Being a bunchgrass, it must be close planted, either broadcast or drilled crosswise of the slope or there will be a tendency under high-velocity conditions for the water to find its way around the clumps in sufficient concentration to make miniature eroding channels. Also the fact that it forms a heavy vegetative mass requires that the main channel have ample carrying capacity or there will be danger of silt accumulations diverting the water to one side and causing cutting. On the other hand, this species lends itself unusually well to waterway protection by reason of its heavy basal growth and the resilience and toughness of its foliage when mature, which tends to "shingle over" and resume normal position in conformity with the vagaries of the current. In general, therefore, by the observance of two major requisites—(1) close planting and (2) ample channel capacity—this grass appears well suited for drainageway planting (fig. 13).



FIGURE 14.—Weeping lovegrass, seeded in 4-foot rows, crosswise to this sandy draw on the upper side of a cultivated field, controlled erosion and protected the land below from washing and siltation the first season. National Observational Nursery, Beltsville Research Center, Beltsville, Md.

In the Northeastern States and in the South Central States weeping lovegrass has been used effectively in producing quick protection for drainageways under severe site conditions, broadcast seedings in some instances making sufficient growth in 5 weeks to prevent the channel from eroding. These observations are in accord with findings at the National Observational Nursery at Beltsville, Md., where this grass within a current growing season made sufficient growth to control erosion completely in a natural draw of a cultivated field. Composed of light sandy soil with 3.75-percent slope, the draw was subjected to severe washing, which made it impossible to utilize that part of the field for growing the usual row crops. The weeping lovegrass was seeded May 26 in 4-foot rows crosswise to the draw at the rate of $\frac{3}{4}$ pound of seed per acre. Two or three fairly good rains occurred during the period of establishment, but the crucial test came in late summer when 3 inches of rain fell within a period of 2 hours. Although completely covered by the rushing floodwaters, neither the grass nor the soil was damaged (fig. 14).

Typical examples of the use of weeping lovegrass for the protection of terrace-channel outlets by farmer-cooperators are to be found on the farms of R. C. Knowles and H. L. Datin in the Cottonwood Creek Soil Conservation District in Oklahoma.⁹ The grass was seeded, in the first instance, in 12-inch drills zigzag across the channel; and in the second instance it was started by the use of seedling clumps transplanted 6 inches apart on 18-inch rows at right angles across the channel. Both plantings have satisfactorily held the soil and prevented washing.

⁹ The development of the waterways was supervised and reported upon by Roy Irwin, work-unit leader, Soil Conservation Service, U. S. Department of Agriculture.



FIGURE 15.—Single closely seeded row of weeping lovegrass along the upper edge of a terrace prevents silt from accumulating in the channel way. Soil Conservation Service nursery, Rock Hill, S. C.

Siltation

Coupled with the necessity of protecting the erodible surfaces of water-conveying channels by the use of vegetative cover is the equally important need, under some conditions, of making artificial plantings to prevent silt from accumulating in these channels. In like manner, it often is necessary, as an integral part of the conservation farm plan, to develop vegetative barriers to catch and disperse the silt before it reaches bodies of water, low-lying crop and pasture lands, and main drainageways. Such barriers may consist of one or more rows above a terrace channel, hillside ditch, highway drain or along a single or double contour furrow; wide bands on the uphill side of diversion ditches; a series of strips of variable width along a cultivated slope; or solid stands extending in part or throughout a local watershed. Under all such conditions these lovegrasses have practical application.

The effectiveness of weeping lovegrass as a siltation barrier became evident several years ago in the operation of Soil Conservation Service nurseries on sloping land. The Rockhill, S. C., nursery was the first to utilize it as a silt filter above terrace and hillside channels. It was found at this nursery that one row of weeping lovegrass thickly seeded or closely clump-transplanted immediately above the terrace channels, effectively filtered out the silt load and prevented inter-terrace washing (fig. 15).

In some farming sections where Bermuda grass is used for sodding the floor of terrace-outlet channels, it has been found that weeping lovegrass thickly planted along the shoulders serves the double pur-

pose of keeping out silt and preventing the Bermuda grass from escaping into adjacent cultivated fields.

Lehmann lovegrass is finding a definite place as filter cover for wide water-conveying swales and flood plains associated with general flood control and range improvement in the Southwest. Although planted usually along contour furrows to facilitate establishment under bare-ground conditions, this grass, owing to its drought-enduring quality and ability to spread by self-seeding, soon functions as widening bands and eventually as solid silt-retaining stands. (See fig. 12.)

As silt-detaining barriers above stock tanks, farm ponds and large reservoirs, these lovegrasses have found greatest use, so far, in the West. Here, where woody plant growth is less common and all plant establishment more difficult, they appear to have definite value for such purposes, especially on sites that have become denuded by overgrazing or that have lost the topsoil by erosion, grading, or other causes.

Strip Cropping

The use of these lovegrasses as siltation barriers proper may be extended appropriately to include the commonly accepted soil conservation practice of strip cropping, as discussed by Enlow and Musgrave (15) and Kell and Brown (25), in which long, cultivated slopes are broken by crosswise bands of close-growing vegetation alternating with strips of open-growing crops.

Weeping and Boer lovegrasses in particular, within their respective growth ranges, lend themselves for use as temporary or permanent soil- and moisture-conserving strips, planted either as solid stands or in contour rows with or without supporting terraces. Their usefulness for this purpose is due in large measure to their dense, heavy top growth (figs. 2, 3, 4, and 8) which not only checks the momentum of the runoff and filters out the silt, as previously indicated, but holds back and utilizes for their own growth and to a marked degree that of the intertilled crop, a proportionately large share of the intercepted moisture. Clarified by this vegetative mass, the runoff penetrates more readily the soils occupied by the intertilled crop, since the ratio of water penetration is in direct proportion to its clearness or freedom from silt. As shown by Lowdermilk (27) and emphasized by Enlow and Musgrave (15), as little as 1.7 to 1.9 percent of solids carried in the water reduced the rate of percolation within 6 hours to less than one-tenth the rate of clear water.

Used as a strip-cropping plant, weeping lovegrass in particular is very effective in the control of wind erosion. It has been found useful for this purpose not only in the low-rainfall, sand-blow regions of the West but also on local areas in the higher rainfall belts where the blowing of fine sand and dry muck are frequently serious menaces. Although mainly summer growing, its basal stems and foliage are retained in normal position without much deterioration until the new growth of the next growing season comes out. This gives year-round soil and intercrop protection.

When lovegrass is seeded at right angles to the prevailing wind irrespective of contour, the practice commonly recommended in plant-

ing most crops used to prevent wind erosion (24, 25), row planting insures greater plant vigor and consequently greater wind resistance than broadcasting. At the Beltsville Research Center, weeping lovegrass planted in single rows at 40-foot intervals crosswise of the rows of cultivated crops, has proved very helpful in controlling wind erosion on sandy fields and has not offered any cultural difficulty.

Soil Building and Crop Rotation

Weeping lovegrass, and to a lesser degree the other two species, exceed most introduced and native grasses with which they have been compared in depth, size, toughness, volume and lignin content of roots, and in the quantity and enduring quality of litter produced for incorporation into the soil. These qualities, which give this grass proportionately greater moisture and plant-food-absorbing and erosion-resisting surfaces, appear to make it unusually valuable for use in soil building and general crop rotation. Such a conclusion is in accord with Dittmer's (14) findings to the effect that some members of the grass family, as shown by careful measurement, have much greater area of root surface than others and are, therefore, superior in soil-building possibilities. Also, as pointed out by Bradfield (7), the more vigorous the growth of the plant the greater the residue left in the soil and consequently the greater the effect on soil structure.

The rooting habit of these grasses has been discussed previously. The relative size, number, and breaking point or toughness of their roots in comparison with those of nine other representative species are given in table 1. The observations upon which these findings are based were made at the National Observational Nursery, Beltsville Research Center, Beltsville, Md., during the summer of 1942. The grasses were planted and grown under uniform conditions. The seed was sown on June 25 in 3-inch clay pots (5 per species) plunged into the open ground. On July 10 the plants were repotted without disturbing their roots to 6-inch pots and thinned to five individuals per pot. Nine weeks after planting, the plants were removed, their roots carefully washed, and the data obtained as recorded in table 1.

The data given in table 1, show that weeping lovegrass surpassed all other species in the number, size, and toughness of main roots per plant. Boer lovegrass was exceeded in number of roots only by weeping lovegrass and orchard grass and in toughness only by weeping lovegrass and side-oats grama. The large number of culms produced by weeping and Boer lovegrasses as compared with the other grasses—a good measure of the rapidity of plant development and relative erosion resistance—also was outstanding. While Lehmann lovegrass fell far below the other two lovegrasses in number of roots and culms per plant, as well as in toughness of roots, this deficiency was counterbalanced in part by the early and rapid development of vegetative offsets from the nodes of prostrate stems.

To obtain a further measure of the contribution of the roots of weeping lovegrass to soil building and erosion control, examinations were made to determine the amount of roots produced by this grass within the first foot of soil in comparison with six common, native and

TABLE 1.—Root and top comparisons of pot-grown specimens of weeping, Boer, and Lehmann lovegrasses and 9 common grasses, 9 weeks after planting

Species	Roots (averages)				Tops (averages)			
	Number per plant	Diameter	Breaking point ¹	Percent	Number culms per plant	Height	Breaking point ¹	Percent
		Inches	Pounds			Inches	Pounds	
Weeping lovegrass (<i>Eragrostis curvula</i>)-----	33	0.044	2.43	31.00	16	24	4.79	69.00
Boer lovegrass (<i>Eragrostis chloromelas</i>)--	21	.037	2.27	23.46	13	24	5.14	76.54
Lehmann lovegrass (<i>Eragrostis lehmanniana</i>)--	12	.027	1.49	19.47	4	32	4.47	80.53
Sand lovegrass (<i>Eragrostis trichodes</i>)-----	21	.025	.87	27.02	4	18	6.84	72.98
Switchgrass (<i>Panicum virgatum</i>)-----	13	.037	2.02	36.03	3	11	5.22	63.79
Side-oats grama (<i>Bouteloua curtipendula</i>)--	10	.029	2.31	24.60	6	12	6.73	75.40
Orchard grass (<i>Dactylis glomerata</i>)-----	29	.022	.51	35.66	5	9	3.26	64.34
Meadow fescue (<i>Festuca elatior</i>)-----	13	.023	.78	35.73	5	8	3.87	64.27
Indian grass (<i>Sorghastrum nutans</i>)-----	13	.029	1.01	45.18	5	8	3.77	54.82
Giant ryegrass (<i>Elymus canadensis</i>)-----	12	.020	.65	36.42	4	6	3.11	63.58
Crested wheatgrass (<i>Agropyron cristatum</i>)-----	16	.017	1.02	39.26	7	5½	4.57	60.74
Buffalo grass (<i>Buckloe dactyloides</i>)-----	7	.019	.85	33.55	3	2	4.01	66.45

¹ Henry L. Scott Co. yarn tester, model X—3 (0-10 pounds capacity).

introduced grasses. The examination was made by use of a special tool¹⁰ which permitted the removal at one time of a plant with the roots intact and 100 square inches of soil to a depth of 1 foot (fig. 16). The cutting blade consists of a hollow square 10 inches across and 12 inches deep with a 3-foot upright handle made of 2-inch pipe. Composed of ⅛-inch sharpened steel plate, the blade is pushed into the ground to the desired depth by the operator standing on the top and working the handle alternately from side to side. Then an excavation is made on one side of the blade, a sharpened garden spade is inserted beneath to sever the connecting roots, and the tool containing the enclosed soil and roots is lifted out.

The data given in table 2 show that the amount of weeping lovegrass roots found in the first foot of soil was slightly more than that of big and little bluestem, almost twice that of blue and side-oats grama, and more than three times that of tall meadow fescue and orchard grass. The most striking difference, however, was the large amount of vegetative material produced by the combined development of roots and tops of the lovegrass as compared to that of all the other grasses. This is attributed to the larger and more persistent year-to-year accumulations of basal leaves and culms.

The root examinations were made in the fall of 1942 after the grasses had completed their third growing season. The plants had been started from seed in 3-inch pots in the greenhouse during February of 1940 and in April had been transplanted as individual plants

¹⁰ Designed by the author and W. W. Steiner, manager, National Observational Nursery, Nursery Division, U. S. Soil Conservation Service, Beltsville Research Center, Beltsville, Md.

TABLE 2.—*air-dry weights per acre of roots and tops of weeping lovegrass compared with 6 common native and introduced grasses*¹

Species	Weight of roots per acre at different soil depths			Weight of tops per acre	Weight of roots and tops per acre
	0-6 inches	6-12 inches	0-12 inches		
	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>
Weeping lovegrass (<i>Eragrostis curvula</i>)-----	5,111	1,523	6,634	41,010	47,644
Big bluestem (<i>Andropogon furcatus</i>)-----	4,909	1,532	6,441	13,100	19,541
Little bluestem (<i>Andropogon scoparius</i>)-----	4,873	1,467	6,340	9,050	15,390
Blue grama (<i>Bouteloua gracilis</i>)--	2,448	756	3,204	7,688	10,892
Side-oats grama (<i>Bouteloua curtipendula</i>)--	1,903	987	2,890	6,773	9,663
Tall meadow fescue (<i>Festuca elatior</i>)-----	1,817	375	2,192	6,391	8,583
Orchard grass (<i>Dactylis glomerata</i>)-----	1,677	165	1,842	5,708	7,550

¹ Calculated from the known weights of roots and tops of three 3-year-old representative individual plants.

to the field on 3-foot rows 1 foot apart in the row. Handled in this manner, the grasses grew in clumps rather than continuously along the row.

In obtaining the root samples of a particular plant the vegetation above ground was cut off flush with the soil surface. A soil block 10 by 10 by 12 inches was taken, one horizontal half at a time, the tool being centered over the crown of the grass. On each side of this, in the direction at right angles to the row, a 10- by 10- by 12-inch block and a 10- by 3- by 12-inch block were then taken, both in



FIGURE 16.—Tool and method of excavation used in determining the amount of root growth contained in the first foot of soil of an individual grass plant.

horizontal halves. This provided a complete cross section of the row totaling 10 by 36 by 12 inches. (See fig. 16.) By placing the soil-root mass from each cut on double close-meshed wire screens and playing on it a carefully regulated stream of water from a fine-nozzled hose, the roots were washed out with no appreciable loss. To insure comparable results, in the case of species bearing shallow rhizomes, the rhizomes were separated from the roots at the time of washing and included in the weights of the tops.

The Lignin Content of the Lovegrasses in Relation to Soil Building and Crop Rotation

Recognizing, as disclosed by Waksman (39), that the lignins are the most resistant of the various plant constituents to decomposition by micro-organisms and that as such, they materially affect the physical character of the soil when crop plants are turned under, the writer initiated tests to determine the lignin content of the lovegrasses. The analyses, which included both roots and tops, were made by W. T. McGeorge, agricultural chemist of the Arizona Agricultural Experiment Station at Tucson. As reported by McGeorge, the lignin content was determined by the method of the Association of Official Agricultural Chemists,¹¹ except for one modification. The nitrogen

TABLE 3.—Comparison of lignin content of the roots of weeping and Boer lovegrasses and two native species, little bluestem and switchgrass. The plants were grown at the Soil Conservation Service nursery, Tucson, Ariz., and the samples were collected December 12, 1942.¹

Species	Age of plant	Lignin	
	Years	Percent	Lignin nitrogen Percent
Weeping lovegrass (<i>Eragrostis curvula</i>)	4	20.20	0.474
Weeping lovegrass (<i>Eragrostis curvula</i>)	2	13.50	.289
Weeping lovegrass (<i>Eragrostis curvula</i>)	1	9.69	.191
Boer lovegrass (<i>Eragrostis chloromelas</i>)	4	18.30	.397
Switchgrass (<i>Panicum virgatum</i>)	4	13.56	.132
Little bluestem (<i>Andropogon scoparius</i>)	4	15.87	.345

¹ Analyses by the Agricultural Chemistry Department, Arizona Agricultural Experiment Station.

contained in the lignin was not subtracted from the crude lignin but was calculated on the basis of percent of lignin nitrogen in oven-dry grass and shown separately. The results of these determinations are given in tables 3, 4, 5, 6, and 7.

Table 3 shows that the lignin content of the roots of weeping and Boer lovegrasses is comparatively high. In comparison with the two native species of somewhat similar growth habit weeping lovegrass presents the stronger contrast, its root system containing over 61½ percent more lignin than that of switchgrass and over 41¼ percent more than little bluestem. This table shows further that the lignin

¹¹ ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. OFFICIAL AND TENTATIVE METHODS OF ANALYSIS . . . Ed. 5, 757 pp., illus. 1940. (See p. 143.)

TABLE 4.—Comparison of chemical analyses of late summer recovery growth of weeping, Boer, and Lehmann lovegrasses with analyses of side-oats grama and slender grama.¹ Grasses planted March 12, 1942 at the Soil Conservation Service nursery, San Antonio, Tex.

Species	Date mowed	Date sampled	Protein	Ether extract	Fiber	Nitrogen free extract	Ash	Lignin	Lignin Nitrogen
			Percent	Percent	Percent	Percent	Percent	Percent	Percent
Weeping lovegrass (<i>Eragrostis curvula</i>)	Oct. 11, 1942	Nov. 18, 1942	9.45	4.41	32.41	47.08	6.65	12.42	0.356
Boer lovegrass (<i>Eragrostis chloromelas</i>)	Oct. 17, 1942	Nov. 18, 1942	10.42	3.00	34.47	44.30	7.81	10.48	0.301
Lehmann lovegrass (<i>Eragrostis lehmanniana</i>)	Oct. 11, 1942	Nov. 18, 1942	8.81	1.71	37.50	45.53	8.45	10.10	0.387
Side-oats grama (<i>Bouteloua curtipendula</i>)	Oct. 17, 1942	Nov. 18, 1942	10.11	1.83	27.81	40.60	19.65	10.42	0.306
Slender grama (<i>Bouteloua pliformis</i>)	Oct. 17, 1942	Nov. 18, 1942	9.00	1.95	30.45	43.73	14.87	9.77	0.340

¹ Analyses made by the Agricultural Chemistry Department, Arizona Agricultural Experiment Station.

TABLE 5.—Comparative chemical analyses of mature green leaves of weeping lovegrass, Boer lovegrass and little bluestem.¹ Samples taken December 12, 1942 from 4-year-old plantings grown under comparable conditions at the Soil Conservation Service nursery, Tucson, Ariz.

Species	Protein	Ether extract	Fiber	Nitrogen free extract	Ash	Lignin	Lignin nitrogen
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Weeping lovegrass (<i>Eragrostis curvula</i>)----	7.36	3.75	31.52	52.16	5.17	11.39	0.296
Boer lovegrass (<i>Eragrostis chloromelas</i>)----	8.88	2.28	33.11	48.61	7.12	10.36	.313
Little bluestem (<i>Andropogon scoparius</i>)----	4.37	2.25	28.73	52.24	12.41	11.36	.171

¹ Analyses made by the Agricultural Chemistry Department, Arizona Agricultural Experiment Station.

TABLE 6.—Chemical analyses of the mature, dry leaves of weeping, Boer, and Lehmann lovegrasses taken in midwinter from 1-year-old plantings at the National Observational Nursery, Beltsville Research Center, Beltsville, Md.¹

Species	Protein	Ether extract	Fiber	Nitrogen free extract	Ash	Lignin	Lignin nitrogen
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Weeping lovegrass (<i>Eragrostis curvula</i>)----	8.75	1.84	36.30	48.94	4.17	13.51	0.282
Boer lovegrass (<i>Eragrostis chloromelas</i>)----	7.50	1.79	34.22	49.98	6.51	11.80	0.269
Lehmann lovegrass (<i>Eragrostis lehmanniana</i>)----	6.40	1.20	40.34	46.36	5.69	13.66	0.226

¹ Analyses made by the Agricultural Chemistry Department, Arizona Agricultural Experiment Station.

content of the roots of weeping lovegrass is influenced decidedly by the age of the plant, the roots of 4-year-old plants having been found to contain more than one-third that of 2-year-old plants and more than double that of 1-year-old plants. This finding is important in showing that to derive maximum benefits from lignin accumulations in the roots, this grass should be allowed to grow for a period of at least 3 to 4 years before being turned under.

The effect of the lignin in contributing to the lasting qualities of the roots of the lovegrasses increases proportionately the value of these grasses as soil-building crops. At the same time, the resistance to decay and the improvement in soil structure induced by the presence of the lignin is reflected in increased moisture-holding capacity and greater resistance to both wind and water erosion. Rotational, soil-building crops having these qualities are especially applicable in subarid, windy situations where soil-organic materials are so vitally important and so difficult to maintain.

The Lovegrasses and Legumes in Relation to Erosion Control and Soil Building

Because of their bunch habit, weeping and Boer lovegrasses lend themselves to association with legumes, especially when there is sufficient rainfall or irrigation for both crops. Sown with these lovegrasses, legumes serve the essential double purpose of increasing the nitrogen content of the soil and filling up the surface spaces not

actually occupied by the grass clumps, which is reflected in greater erosion control and soil building capacity. This observation is in line with the conclusion of Etheridge and Helm (16) to the effect that Korean lespedeza seems more suitable for association with the bunch grasses than with grasses which form a dense sod.

Present experience indicates that in localities where they are adapted, alfalfa, red clover, alsike clover, ladino clover, bur-clover, hop clover, crown vetch, birdsfoot trefoil, annual lespedeza, and the lower-growing, fine-leaved perennial lespedezas, in well-balanced seeding rates, may be grown satisfactorily in mixtures with weeping and Boer lovegrasses. Particularly desirable combinations are formed by the use of the cool-season perennial or self-seeding legumes which compete less in growing season with these grasses. Also because of their mutual ability to become established quickly on poor sites, develop increasingly dense growth, and accumulate large amounts of carry-over litter, lovegrass and annual lespedeza make an excellent combination where soil-building and erosion control are prime considerations.

The compatability of weeping lovegrass and annual lespedeza has been well demonstrated in a field-scale establishment study on the Northwest Arkansas Land Utilization project, near Fayetteville, Ark. After 3 seasons of growth on "worn-out" farmland, the two crops were observed to have formed a dense grass-legume mass with the good qualities of the one supplementing the deficiencies of the other (fig. 17).



FIGURE 17.—Weeping lovegrass and annual lespedeza growing as a mixture furnish excellent erosion-resistant, soil-building ground cover.

Rotation Practices with Weeping Lovegrass

The Lincoln County Soil Conservation District in Oklahoma was the first to utilize weeping lovegrass as a rotation crop for soil improvement. The practice was initiated by Work Unit Leader, Charles Kilpatrick, of the Soil Conservation Service, and is designed to be flexible and at the same time to insure maximum beneficial effects from the use of the grass.

The basic rotation plan provides that the lovegrass occupy the land for at least 2 years. This affords time for the development of a deep, heavy root system before it is turned under. The plan also provides that the lovegrass be planted in contour strips where needed, alternating with the other crops used in the rotation.

The weeping lovegrass not only serves as a protective soil cover but is utilized for early spring and fall pasturage and seed production, without lessening its efficiency for soil improvement. It is turned under in early winter so that the vegetative material will have time partly to disintegrate by seeding time the following spring. Four and 5-year rotation plans have been placed in effect with corn, cotton, peanuts, and grain sorghum among the major farm crops composing the rotations.

Orchard Soil Cover

The lovegrasses are too new to have found their proper place under the various orcharding conditions and cover-cropping systems that obtain throughout the range of their adaptation. However, the qualities which make these grasses useful as general ground-cover, strip-cropping, desilting and soil-building crops, as well as their adaptability to mixture with legumes, recommend them for use in many instances for orchard soil-cover purposes.

Cooperative studies by the Maryland Agricultural Experiment Station and the Soil Conservation Service were initiated in 1941 to determine the combined erosion-control and general orchard soil-cover values of weeping lovegrass in comparison with some of the more common grasses.

While the studies are not far enough advanced for conclusive interpretation, it can be said that the lovegrass has produced a good erosion-resistant ground cover with no apparent ill effects upon tree growth or fruiting (fig. 18A). In evaluating this grass for orchard soil cover the third year after planting, technicians of the Maryland Agricultural Experiment Station and the Soil Conservation Service list as its principal assets: (1) Efficiency in controlling erosion; (2) ability to grow in partial shade; (3) lasting quality of the hay when used as litter mulch around the trees; (4) capacity for building up a heavy mulch from below; and (5) the cushioning effect of the foliage in preventing bruising of the fruit when, as in the case of some varieties of apple, it is allowed to drop to the ground before being harvested.

The Arizona Agricultural Experiment Station has found weeping lovegrass useful as a cover crop in citrus orchards. Investigations by Martin (28) at the University of Arizona Yuma Mesa Experimental Farm (1937-41) showed that nonleguminous cover crops in grapefruit orchards caused a lowering of the nitrogen content of



FIGURE 18.—A. Weeping lovegrass (left) and orchard grass (right) at end of third year in a cover-crop test in a 4-year-old peach orchard at the Maryland Agricultural Experiment Station Farm, College Park, Md. These grasses had been mowed twice during the summer, before being photographed. B. Weeping lovegrass cover crop in a grapefruit orchard at the Arizona Agricultural Experiment Station Farm, Yuma, Ariz., utilized primarily to lower the nitrogen content of the trees during summer and thus improve the character of the fruit.

the trees through the summer, and thus had a definite influence in improving the size, color, yield, and quality of the fruit. Sudan grass was used as an initial indicator crop, seeded in the spring following applications of quickly available nitrogenous fertilizer during winter. Subsequent findings in cooperative orchard cover-cropping tests by the Arizona Agricultural Experiment Station and the Soil Conservation Service¹² show that weeping lovegrass also has distinct value for the same purpose (fig. 18, *B*).

Preliminary trials also indicate that weeping lovegrass has a valuable function when used in narrow broadcast or row bands along the middle of the tree rows of steep, untterraced, contour-planted orchards. By this usage the grass serves somewhat as living terraces in controlling erosion, conserving moisture, and retaining the silt



FIGURE 19.—Mixture of weeping lovegrass and annual lespedeza holding the soil of an artificially prepared 60-percent slope at an Army post in Maryland. 4 months after seeding.

on the hillside. Moreover, the bands of grass do not preclude the adoption of additional cultural methods, including the growing of some other type of cover on the remaining open areas.

Cover for Man-made Bare Ground

In general, wherever they have been tried out on man-made bare ground such as drainage ditches, dikes, and areas around airports, landing strips and Army camps, the lovegrasses have been comparatively easy to establish and have produced good ground cover quickly (fig. 19). A seeding of weeping lovegrass on cuts and fills along a highway near Zanesville, Ohio, made May 13, gave adequate bank protection by July 15, and although the planting became dormant after the first heavy frosts the foliage decomposed slowly and also gave excellent cover during winter. This grass when transplanted in bunches 18 to 36 inches apart on highway fills near Rock Hill, S. C., furnished complete vegetative cover in two growing seasons

¹² A. H. Finch, head, Department of Horticulture, University of Arizona, Tucson, Ariz., in official correspondence.



FIGURE 20.—Lehmann lovegrass and scattered clumps of weeping lovegrass during the third growing season after seeding, forming embankment cover along a 30-mile section of highway near Benson, Ariz.

with less rapid growth on unimproved, raw cuts. Also it has been used effectively in the Northeast as protective cover along loose drainage-ditch and canal banks, notably on the slopes of the Delaware-Chesapeake Canal.

An outstanding demonstration of the ease of establishment, persistence and effectiveness of Lehmann and weeping lovegrasses for highway embankment cover under extremely adverse conditions is to be seen along Federal Highway 80 in the vicinity of Benson, Ariz. That portion of Arizona has an annual rainfall of only 11 to 12 inches. The terrain through

which the highway runs is mostly very rough and is characterized by shallow, alkaline soils with caliche and granite rock outcrops.

The planting was made in the summer of 1941.¹³ Seeded with the two lovegrasses were two local grasses, side-oats grama, and Rothrock grama. The mixture, at the rate of 2 pounds per acre for each of the lovegrasses and 10 pounds per acre for each of the gramas, was broadcast by hand over all new earthwork and other disturbed areas along the highway right-of-way for a distance of about 30 miles, for the most part without being covered.

Lehmann and weeping lovegrasses became well established during the first growing season, forming almost continuous bands of protective soil cover along both sides of the highway from one end to the other of the seeded strips (fig. 20). Although subjected to prolonged droughts the succeeding 4 years, they have persisted in maintaining themselves. Lehmann lovegrass, supported by scattered clumps of weeping lovegrass in the more favored locations, constitutes by far the largest proportion of the stand and is the only one of the four

¹³ From unpublished reports by A. F. Kinnison, Arizona State Conservationist, Southwestern Region, Soil Conservation Service; E. C. Tatum, district conservationist, Southwestern Region, Soil Conservation Service; and L. P. Hamilton, manager, Soil Conservation Service nursery, Tucson, Ariz.

grasses that developed new plants by self-seeding. Rothrock grama, which at first made up about 30 percent of the stand, gradually disappeared, and the original scattered plants of side-oats grama have failed to multiply.

RELATED ECONOMIC USES

There is an abundance of farm land throughout the country upon which erosion is so great as to justify the planting of whatever crop will best correct the condition, irrespective of whether or not it may have other uses. On the other hand, where the erosion problem is less dominant, the value of the crop is proportionate to its usefulness beyond that of actually conserving the soil, the ideal crop being one that both conserves the soil satisfactorily and furnishes a direct income to the farmer.

The lovegrasses are beyond question excellent erosion-control grasses. Sufficient time has not elapsed since their introduction for them to have been subjected to the critical investigation and large-scale usage necessary for a complete understanding of their other uses and economic relationships. At the same time, enough chemical analyses, palatability tests, practical feeding trials, and general utility observations have been made to furnish a fairly substantial measure of their forage values and the part they may be expected to play in contributing directly to food production and agriculture generally.

Nutritional Determinations and Values

Chemical analyses show that the lovegrasses compare favorably in food values with our more common range, pasture, and hay grasses including both native and introduced species. Data resulting from recent analyses of these grasses at different stages of growth or maturity and some of the good native species are presented in tables 4, 5, 6, 7, 8, and 9. Additional data, adapted from Morrison's *Feeds and Feeding* (30), that include analyses of some of the more commonly used native and introduced species, appear in table 10.

The forage materials used for the determinations given in table 4, in which data resulting from chemical analyses of the three lovegrasses are compared with each other and with two native gramas, as well as the material used to secure the data given in table 7, which pertains only to weeping lovegrass grown at widely separated locations, represent growth such as might be utilized for late summer grazing or hay, while that used for the determinations given in table 8 represents spring growth such as might be utilized for spring and early summer grazing. On the other hand, the analyses shown in table 5 in which weeping and Boer lovegrasses are compared with each other and with little bluestem, represent mature, green leaf growth such as might be used for late fall or winter pasturage in warmer sections. At the same time, the analyses presented in table 6,

involving all three of the lovegrasses, are of material such as might be used for dry winter pasturage.

Protein, one of the most valuable, and crude fiber and lignin, two of the least desirable organic constituents of animal feed, have been largely used as the basis for estimating the nutritive values of these lovegrasses.

Two methods of correlation were employed: (1) comparison of the chemical analyses of the lovegrasses and three good native grasses produced and sampled under practically the same conditions, as given in tables 4 and 5, and (2) comparison of the chemical analyses of the lovegrasses, as given in tables 4, 5, 6, 7, 8, and 9 and representative native and introduced species as taken from Morrison (30) and presented in table 10.

Table 4 shows that the late summer recovery growth of weeping lovegrass was slightly lower and that of Boer lovegrass slightly higher in protein content than side-oats grama with both a little higher than slender grama; whereas, Lehmann lovegrass at this stage was a little lower in protein than either of the two gramas. In round figures, the crude-fiber content of weeping, Boer, and Lehmann lovegrasses ranged 4, 6, and 9 percent higher, respectively, than side-oats grama and 2, 4, and 7 percent higher than slender grama.

As shown in table 5, the protein content of the fully mature, green forage of weeping and Boer lovegrasses was about double that of little bluestem, one of our very good, widely adapted native species. In the same order, these grasses were approximately 2 and 4 percent higher in crude fiber.

The determinations given in table 6 are significant in that they show that the lovegrasses had relatively high nutritive value during winter, after most of their foliage had been killed by frost.

The analyses of the late summer recovery growth of weeping lovegrass produced under various conditions throughout the country and sampled at different periods, summarized in table 7, and the analyses of different types of spring growth given in table 8, show that in both of these stages this grass had a generally high protein content. The material highest in protein was grown at Beltsville, Md., on rather poor, unfertilized sandy loam soil. The sample composing the late summer recovery growth, which contained 14.65 percent protein (table 7), was 4 weeks old; and that composing the spring growth, which contained 15.49 percent protein (table 8), was a little over 7 weeks old. The material next highest in protein content (13.53 percent, table 7) was from the Rock Hill, S. C., nursery where the soil is decidedly sandy and only moderately fertile. This sample was composed of late summer recovery growth about 8 weeks old, following accidental burning. The significance of these two sets of determinations is in showing that under favorable conditions the new growth of weeping lovegrass taken at any time during the growing season may be expected to have relatively high food value.

It is more or less generally understood, as discussed by Crompton and Maynard (10), Norman (31), Waksman (39) and others, that the digestibility of stock feed is influenced adversely by the presence of lignin. The lignin content of the forage parts of the lovegrasses

TABLE 7.—Comparison of chemical analyses of late summer recovery growth of creeping lovegrass in widely separated localities

Localities	Time of planting	Date mowed	Date sampled	Height	Protein	Ether extract	Fiber	Nitrogen free extract	Ash	Lignin	Lignin nitrogen
				<i>Inches</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
Mesa, Ariz. ¹	April, 1941	Sept. 10, 1942	Nov. 12, 1942	18-24	9.81	3.02	32.84	47.30	7.03	9.90	0.257
San Antonio, Tex. ¹	March, 1942	Oct. 17, 1942	Nov. 18, 1942	15-18	9.45	4.41	32.41	47.08	6.65	12.42	.356
Sibley, La. ²	April, 1940	Sept. 29, 1942	Nov. 18, 1942	10-12	10.31	2.93	33.14	40.07	4.55	12.01	.243
Rock Hill, S. C. ¹	April, 1939	Late Sept. 1942 ²	Nov. 25, 1942	15-18	13.53	3.26	28.24	50.03	4.94	11.21	.437
Beltsville, Md. ¹	June, 1942	Sept. 21, 1942	Oct. 28, 1942	10-12	14.65	2.72	31.10	45.87	5.66	11.51	.297
Stillwater, Okla. ³	April, 1942	Sept. 10, 1942	Oct. 28, 1942	15-18	9.18	2.79	30.86	43.46	4.91	---	---
Minden, La. ⁴	April, 1941	Aug. 13, 1942	Sept. 10, 1942	15-18	9.56	2.36	36.70	40.28	3.65	---	---

¹ Analyses made by the Agricultural Chemistry Department, Arizona Agricultural Experiment Station.² Tops burned off.³ Analyses made by the Agricultural Chemistry Department, Oklahoma Agricultural Experiment Station.⁴ Analyses made by the Agricultural Chemistry Department, Louisiana Agricultural Experiment Station.TABLE 8.—Chemical analyses of spring recovery growth of creeping lovegrass the third season after planting.¹ Samples composed of different-age growth originating from fall and spring-mowed grass in the same field.

Time older growth was mowed off	Leaf growth			Analyses						
	Age	Type material	Height	Water	Ash	Ether extract	Nitrogen	Crude protein	Nitrogen free extract	Crude fiber
			<i>Inches</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
Previous fall	30 days	First clipping	9-11	7.75	3.38	2.08	1.850	11.62	41.74	30.43
Previous fall	51 days	First clipping	16-18	7.10	4.25	2.95	2.479	15.49	39.79	30.42
Previous fall	21 days	Second clipping	10-12	7.35	4.40	3.05	2.426	15.16	39.47	30.57
Current spring	30 days	First clipping	6-8	7.65	3.40	2.20	2.067	13.11	41.94	28.70
Current spring	51 days	First clipping	15-17	7.20	4.20	3.00	2.220	13.88	41.32	30.40
Current spring	21 days	Second clipping	8-10	7.40	4.55	3.13	2.397	14.98	39.64	30.30

¹ Analyses made by Bureau of Dairy Industry Experiment Station, United States Department of Agriculture, Beltsville Research Center, Beltsville, Md.

is given in tables 4, 5, 6, and 7. These analyses show that the amount of lignin contained in the leaves of these grasses compares favorably with that of side-oats grama, slender grama, and little bluestem (tables 4 and 5), being slightly higher in some instances and slightly lower in others.

Based upon findings of Patton (32) and Stanley and Hodgson (38), the leaves of the lovegrasses at comparable growth stages are lower in lignin than those of blue grama, one of the best native grazing grasses. For example, the range in lignin content of weeping lovegrass is from 9.90 percent (table 7) to 13.51 percent (table 6), while that of blue grama given by Patton is from 12.60 to 15.20 percent.

The lignin determinations of weeping and Boer lovegrasses are especially significant. They show that although the roots of these grasses are unusually high in lignin (table 3), which favors their usefulness for soil conservation, the lignin content of the tops is not such as to impair their feeding value.

Comparable analyses of weeping lovegrass and two good native grasses (little bluestem and blue grama), are given in table 9. These grasses were grown at the Red Plains Conservation Experiment Station,¹⁴ Guthrie, Okla., on soils of a similar nature in the same field, but all very low in phosphorus. The results are significant in showing that the weeping lovegrass in comparison with the native grasses was relatively high throughout the growing season in the important element of nitrogen and not appreciably low in phosphorus and calcium. It was decidedly low in ash.

Similar comparisons of weeping lovegrass (table 9) and the three common pasture and hay grasses in table 10 for which complete analyses are given (Bermuda grass, Kentucky bluegrass, and timothy), shows that the lovegrass was considerably higher in nitrogen than all of these grasses and slightly higher in calcium than Kentucky bluegrass and timothy. However, the phosphorus content of the common grasses was more than double that of the lovegrass.

A comparison of the chemical analyses of the lovegrasses given in tables 4, 5, 6, 7, and 8 with those of the common pasture and hay grasses given in table 10 shows that the lovegrass at all stages of growth was higher in protein content. On the other hand, the common grasses contained appreciably less crude fiber.

While the chemical analyses here discussed show the food content of the lovegrass when sampled, they do not show fully the measure of usefulness of these grasses for forage purposes. This depends not only on food content but also other factors, including more especially digestibility and palatability, which in turn depend largely upon the condition or form in which the grass is utilized and the class and age of the animals to which it is fed. It is common knowledge that a particular grass may be eaten or digested more readily by one class of livestock than another and that its palatability and feeding quality are affected directly by the stage of maturity of the forage and whether or not it is grazed or fed as hay. Unfortunately, there

¹⁴ H. M. Elwell, assistant soil conservationist, Red Plains Conservation Experiment Station, Soil Conservation Service, Guthrie, Okla. From an unpublished report.

TABLE 9.—Percent total nitrogen and minerals in creeping lovegrass and native grasses at different stages of growth, Red Plains Conservation Experiment Station, Guthrie, Okla.¹

Item Studied ²	April	May	June	July	August	September	Average
Weeping lovegrass (<i>Eragrostis curvula</i>):							
Calcium.....	0.360	0.355	0.368	0.333	0.312	0.416	0.357
Phosphorus.....	0.054	0.064	0.059	0.067	0.100	0.044	0.065
Nitrogen.....	1.907	1.554	1.439	1.348	1.806	1.004	1.510
Ash.....	13.980	10.120	5.990	5.470	5.660	6.950	8.030
Little bluestem (<i>Andropogon scoparius</i>):							
Calcium.....	0.459	0.577	0.471	0.462	0.400	0.473	0.474
Phosphorus.....	0.075	0.080	0.078	0.071	0.090	0.042	0.073
Nitrogen.....	1.327	1.458	1.458	0.960	0.987	0.462	1.087
Ash.....	14.720	15.020	13.110	10.490	10.000	8.590	11.990
Mixed native grass:³							
Calcium.....	0.575	0.408	0.413	0.491	0.470	0.606	0.494
Phosphorus.....	0.065	0.062	0.065	0.066	0.094	0.044	0.066
Nitrogen.....	1.284	1.292	1.179	1.095	1.230	0.693	1.129
Ash.....	11.310	12.030	10.690	11.420	13.090	8.710	11.210
Blue grama (<i>Bouteloua gracilis</i>):							
Calcium.....	0.344	0.361	0.402	0.367	0.337	0.331	0.357
Phosphorus.....	0.091	0.091	0.090	0.078	0.097	0.064	0.085
Nitrogen.....	1.509	1.238	1.174	1.040	1.179	0.731	1.145
Ash.....	13.320	13.360	12.870	12.710	13.440	11.170	12.810

¹ Analyses by the Agricultural Chemistry Department, Oklahoma Agricultural Experiment Station. The data compiled for April, May, June, and July are averages for 1940 and 1941, while that for August and September is for 1940 only.

² The different grass samples were taken from soils with similar nutritive values, but all were very low in available phosphorus.

³ These samples were taken from an area consisting largely of little bluestem (*Andropogon scoparius*), Big bluestem (*Andropogon furcatus*), switchgrass (*Panicum virgatum*), Indian grass (*Sorghastrum nutans*) side-oats grama (*Bouteloua curtipendula*) and blue grama (*B. gracilis*).

TABLE 10.—Average composition and digestible nutrients of representative range, pasture and hay grasses ¹

Feeding Stuff (dry roughages)	Total dry matter	Di- gestible protein	Total digestible nutrients	Nutritive ratio	Average total composition						Mineral and fertilizing constituents				
					Protein	Fat	Fiber	Nitrogen free extract	Mineral	Number of analyses	Calcium	Phos- phorus	Nitrogen	Potas- sium	
Bermuda grass hay	90.7	3.7	43.0	10.6	7.3	1.8	25.6	48.4	7.6	17	0.48	0.20	1.17	1.42	
Bluegrass hay, Kentucky (all analyses)	89.4	4.7	53.3	10.3	8.2	2.8	29.8	42.1	6.5	25	0.30	0.22	1.31	1.26	
Bluestem hay (<i>Andropogon spp.</i>)	86.6	2.5	48.2	18.3	5.4	2.2	30.2	43.4	5.4	51	---	---	0.86	---	
Fescue hay (Meadow)	89.2	4.3	52.3	11.2	7.0	1.9	30.3	43.2	6.8	25	---	0.20	1.12	1.43	
Gamma grass hay (<i>Bouteloua spp.</i>)	80.8	3.5	51.1	13.6	5.8	1.6	28.9	45.6	7.9	59	---	---	0.93	---	
Switchgrass hay (<i>Panicum virgatum</i>)	90.0	2.4	43.1	17.0	5.9	2.0	30.4	46.0	5.7	18	---	---	0.94	---	
Timothy hay (all analyses)	88.7	2.9	46.9	15.2	6.2	2.4	30.1	45.0	5.0	266	0.27	0.16	0.99	1.36	

¹ Data adapted from Morrison's Feeds and Feeding (30).

is on record in this country only one digestion trial with these lovegrasses. This trial was with weeping lovegrass in one form and with only one class of animals, and was made by the Oklahoma Agricultural Experiment Station.¹⁵

Weeping lovegrass hay of good quality was ground and fed to 4 Rambouillet yearling sheep for a 40-day period, beginning August 2, 1942, and fecal collections and analyses were made during the last 10 days of the trial. One lamb refused feed the second day of collection, and failing to regain appetite, was dropped from the experiment. As shown by chemical analyses, the ground hay contained 9.18 percent protein, 2.79 percent fat, 30.86 percent fiber, 43.46 percent nitrogen-free extract, 4.91 percent ash and 8.80 percent moisture. Based upon these determinations, the apparent digestion coefficients secured in this trial and expressed as averages were as follows: Protein, 63.7; fat, 45.6; fiber, 65.3; nitrogen-free extract, 53.4.

According to the calculation formulas by Morrison (30), the weeping lovegrass hay, used in this experiment, contained 5.85 percent digestible crude protein and 53.07 percent total digestible nutrients. These data compare favorably with similar data for the best range, pasture, and hay grasses, as evidenced by the analyses of the representative grasses presented in table 10. The weeping lovegrass exceeded all the grasses in this table in digestible crude protein and all except one (Kentucky bluegrass) in total digestible nutrients.

In commenting on the results of the digestion trial at the Oklahoma station, the investigators pointed out that while the ground lovegrass hay was quite digestible when fed to sheep under the conditions of the trial, it was apparently not palatable and the animals would not consume it in large enough quantities to make the grass valuable as a sheep hay. These investigators stated further that the toughness of the hay made grinding necessary and that it took the wethers some time to become accustomed to the prickly nature of the ground hay. The hesitancy of the sheep to eat the lovegrass hay in this form is in line with general observations that this grass is relished less by sheep than by any other class of animals to which it has been fed.

Palatability

The readiness with which lovegrasses are eaten by livestock depends largely on: (1) Whether the forage is grazed or made into hay; (2) stage of maturity when utilized; (3) class of livestock to which it is fed; and (4) the kind of feed to which the animals previously were accustomed. As both pasturage and hay, the principal classes of livestock appear to prefer them in the following descending order: Horses, cattle, and sheep. All animals graze them readily when the new growth is soft and tender which, as shown by analyses already presented, coincides with the period of highest nutritive content.

Horses and mules usually eat lovegrasses with fondness in practically all stages of growth either as green forage or hay. Although cattle graze them with apparent relish and without discrimination in

¹⁵ In an unpublished report by H. M. Briggs, associate animal husbandman, H. W. Staten, agronomist, H. Grauman, assistant agronomist, and V. G. Heller, agricultural chemist, of the Oklahoma Agricultural Experiment Station.

comparison with other grasses while the new growth is fresh and tender, they eat the forage less readily as it approaches maturity. As in the case of most grasses, cattle have been known to refuse to eat the older, midsummer growth unless forced to do so. On the other hand, during fall and winter in the warmer sections, they have not only been found to graze these grasses readily, but in some instances seem to prefer their green basal leaf growth to the drier native species. Both beef and dairy cattle have been observed to eat lovegrass hay satisfactorily where the grasses were mowed during their earlier growth stages and properly cured. Usually, however, animals do not relish hay that is cut after the grasses reach the mature, seeding stage. Sheep have shown less fondness for the lovegrasses than most animals, but they usually graze the new growth readily and appear not to discriminate against these grasses except in the form of hay.

Observational Grazing Trials

Comparative grazing trials with weeping lovegrass were conducted by the Northeast Louisiana Experiment Station during 1941-43.¹⁶ In the spring of 1941 a 6-acre pasture planting was established, 1 acre being planted to a mixture of weeping lovegrass and red clover and the remaining 5 acres to a mixture of Dallis grass and red clover. The grazing period during the first summer, with six 2-year-old grade Hereford steers, was from July 1 to October 1 and during the second summer, with twelve 2-year-old grade Hereford steers, from March 23 to November 1. The weeping lovegrass was grazed as closely as the Dallis grass and so far as could be observed, the two were equally palatable. In 1943, grazing was begun on April 1 with 6 head of grade Hereford long yearlings. This number was increased shortly to 12 and later to 16. The total gain in weight of the cattle to August 1 was at the rate of 430 pounds per acre. This was 97.5 pounds per acre greater than the gains obtained from the same size pasture consisting of Bermuda grass and white Dutch clover with a similar grazing procedure. The weeping lovegrass showed early, vigorous growth each spring and appeared to remain nutritious under heavy grazing.

In cooperative grazing trials with a weeping lovegrass-native grass (mainly blue and side-oats grama) mixture at the Panhandle Agricultural and Mechanical College, Goodwell, Okla.,¹⁷ in the summer of 1942, the gains in weight made by the cattle were very good during periods when the lovegrass was fresh and palatable and correspondingly low as it approached maturity and became unpalatable.

During the succeeding fall and winter this same weeping lovegrass-native grass mixture was checked against native grass pasturage, composed mainly of buffalo grass and blue grama. Six yearling Hereford steers were used, three for the lovegrass-native grass mixture, and three for the native pasturage, supplemented in each case by a daily ration of 1 pound of cottonseed cake. For the first 4 weeks, beginning November 19, the steers on the lovegrass-native grass mixture showed

¹⁶ C. B. Haddon, superintendent of the station, in official correspondence.

¹⁷ From an unpublished report by W. N. McMillen, professor of Animal Husbandry, Panhandle Agricultural and Mechanical College.

an average daily gain of 2.77 pounds compared to 1.88 pounds for those on the native grasses alone, a difference of 0.87 pound in favor of the former; but for the entire winter period of 152 days the average daily gains produced by the lovegrass-native grass mixture were only slightly greater than those produced by the native grasses alone.

The two groups of steers were continued on these same pastures the following summer. For the first 10 weeks of the grazing period, May 15 to August 1, while the lovegrass was more palatable, the animals grazing the lovegrass-native grass mixture made an average daily gain of 2.28 pounds as against 1.50 pounds for those on the native grass alone. However, during the latter part of the grazing period, August 1 to September 26, after the lovegrass had reached maturity and become less palatable, the steers on the lovegrass-native grass mixture gained only 0.97 pound daily compared to 1.53 pounds for those on the less mature native grass. The forage yield of the lovegrass was about 4 times that of the native grass.

In summarizing this series of grazing trials, it was the general observation that whether utilized separately or in mixtures the lovegrass and native grasses were grazed without preference. The only time the lovegrass was grazed less readily was in midsummer, after it had become mature and coarse, before the slower growing, later maturing native grasses had reached a similar stage of maturity. It was notable that for the full 9-month grazing period, including parts of the fall, winter, spring, and summer of 1942-43, the lovegrass-predominated mixture produced slightly greater animal gains than the native grama-buffalo grass pasture. Most significant, however, were the decidedly superior gains produced by this grass during the spring and early summer and during the fall when it was in its most palatable stages. These results show that with proper pasture management, weeping lovegrass is an excellent pasture grass in the Panhandle section of the Great Plains and that it can be utilized to best advantage for this purpose in early spring and summer and during the dormant season with a concentrate supplement such as cottonseed cake.

The Soil Conservation Service and the Arizona Agricultural Experiment Station conducted a fall and winter grazing trial with weeping and Lehmann lovegrasses in comparison with native species under range conditions on the ranch of R. C. Larimore near Sonoita, Ariz., during 1940-41.¹⁸ These lovegrasses, singly and mixed, were established during the summer of 1939 in triplicated 10- by 436-foot strips alternating with similar-sized strips of undisturbed native sod composed mainly of three-awn grasses (35 percent), curly mesquite (30 percent), blue grama (25 percent), hairy grama (5 percent) and side-oats grama (5 percent). The grazing plots were located about 1 mile from stock water in a 380-acre range pasture, and in the fall of 1940 the exclusion fence was removed and 25 head of cattle allowed to graze at will over the entire area. Periodic utilization estimates and notes were made during the succeeding 6 months, as recorded in table 11.

¹⁸ From an unpublished report by E. B. Stanley, animal husbandman of the Arizona Agricultural Experiment Station, J. D. Freeman, range examiner of the Southwestern Region of the U. S. Soil Conservation Service at Patagonia, Ariz., L. P. Hamilton, manager of the U. S. Soil Conservation Service nursery at Tucson, Ariz., and K. W. Parker, forest ecologist of the Southwestern Forest and Range Experiment Station of the U. S. Forest Service at Tucson, Ariz.

TABLE 11.—*Utilization of weeping and Lehmann lovegrasses in comparison with native perennial grasses as range pasturage near Sonoita, Ariz., during the winter of 1910-11*

Date of examination	UTILIZATION			Remarks
	Weeping lovegrass	Lehmann lovegrass	Native species	
	Percent (%)	Percent		
Oct. 1	---	---	Slightly	Cattle showed fondness for the seed heads and culms of weeping lovegrass. Native grasses dry. Basal leaves of lovegrasses still green and apparently very palatable. Weeping lovegrass proved more palatable during fall than Lehmann lovegrass and the native grasses. Weeping lovegrass being used most heavily. Weeping lovegrass taken readily all fall. Lehmann lovegrass taken to some extent the past few weeks. No additional use detected, seemingly owing to feed being plentiful throughout main pasture. Basal leaves of lovegrasses remained green all winter and apparently were preferred to the dried native grasses.
Oct. 14	---	None	Slightly	
Oct. 28	30	None	Less than 10 percent each	
Nov. 7	35	5	Less than 10 percent each	
Nov. 27	40	10	Less than 10 percent each	
Dec. 1	65	15	Less than 10 percent each	
Jan. 1	70	15	Less than 10 percent each	
Jan. 25	---	---	---	
March 7	80	30	10 percent each	
April 1	---	---	---	
May 1	---	---	---	No appreciable use; feed plentiful all through pasture. Nonuse of exotic and native perennial grasses during April and May apparently due to abundance of annual spring growth.

¹ Mainly the seedstalks were utilized.

As shown in this table, the percentages of utilization for the entire dormant season were significantly in favor of the lovegrasses—totaling 80 percent for weeping lovegrass and 30 percent for Lehmann lovegrass, as against 10 percent for the native species. The decided preference for the lovegrasses doubtless can be attributed to the fact that during winter in this section the basal portion of the leaves and stems of these grasses remains green and succulent, and consequently more palatable than the native grasses, which usually dry up by the middle of November.

At the Albuquerque, N. Mex., nursery in 1943, seed-production plantings of Boer and weeping lovegrasses were utilized during the period between harvests for observational winter and early spring grazing trials.¹⁹ Five range Hereford cows were allowed to graze a 7-acre field of Boer lovegrass for 24 days, beginning January 8, followed by the grazing of a 6-acre field of weeping lovegrass for 48 days. The grasses were then mowed to insure uniformity of development and, after an interval of 27 days to allow the spring growth to form, they were again grazed for short periods—first the weeping lovegrass, which developed faster, and then the Boer lovegrass. Both grasses were grazed readily during the winter period, the cattle seeming to relish the leafage closer to the base of the plants, which remained somewhat green and succulent all winter. Spring grazing was started when the new growth had attained a height of 6 to 12 inches. Taken directly from a Harding grass (*Phalaris tuberosa stenoptera*) pasture to weeping lovegrass, the cattle ate the latter greedily, and subsequently, when they were transferred to Boer lovegrass, this species as well was eaten with relish. The two grasses were spring-grazed 11 and 15 days respectively, before being allowed to continue growth for the next seed crop. The cows remained in good condition while feeding on the lovegrasses.

At the Tucson, Ariz., nursery it has become a practice to pasture the heavy aftermath of seed-production plantings of these lovegrasses to horses, beginning in early winter and continuing until all available green and dry growth is consumed. The horses show a fondness for the grasses, graze them readily, and keep in good condition. Their manner of grazing is first to eat the green inside basal growth and recently established seedlings and then to eat the drier leaves and culms (fig. 21).

Farmer-cooperator Plantings

As a means of final evaluation, seeds of these lovegrasses alone and in mixtures with the more common native and introduced species were made available to farmer cooperators in various parts of the country for trial. The resulting plantings, varying in size from 1/4 acre to more than 100 acres, were established under a wide variety of soil, rainfall, temperature, and erosion conditions. Considered first from the standpoint of soil conservation values, the seedings for the most part were made on the poorest, most badly eroded soils of the particular locality.

One of the first farmer cooperators to have demonstrated the prac-

¹⁹ From an unpublished report by J. A. Downs, manager, Soil Conservation Service nursery, Albuquerque, N. Mex.



FIGURE 21.—Seed-production field of Boer lovegrass following grazing of aftermath growth by horses at the Soil Conservation Service nursery, Tucson, Ariz.

tical feeding value of weeping lovegrass was C. I. Pumroy, of Gallegos, N. Mex. Mr. Pumroy made a 6-acre planting in 1938, which by 1940 had increased through volunteering to about 8 acres. This planting was made in part of a cultivated field in which sorghum was grown each year as a major feed crop. The grass was planted in 42-inch lister rows and cultivated the first season.

Adjacent to this field was a native-grass pasture composed principally of blue grama, side-oats grama, sand bluestem, and little bluestem, with scattered plants of buffalo grass on the flats. Beginning with the winter of 1939-40, each winter the fence was let down between the native-grass pasture and the cultivated field containing the lovegrass and the residue from the sorghum crop. The cattle exhibited a decided preference for the lovegrass, consuming all the growth produced during the previous growing season. It was found also that horses, cattle, goats, and buffalo ate the grass with relish during the summer in the form of either green or cured hay.²⁰

Farmer-cooperator J. R. Righter, Broken Arrow, Okla., is one of the many farmers who found weeping lovegrass useful both for erosion control and stock feed. He planted the lovegrass to correct a severe wind-erosion condition, but beginning the second year he has utilized it as well for hay, cutting two crops a year and finding that both cattle and horses eat the hay satisfactorily and do well on it. In like manner, Farmer-cooperator R. L. Ramer, Marmaduke, Ark., reported that a planting of this grass on his farm was successfully controlling water erosion on a 14-percent slope and at the same time

²⁰ From an unpublished report by J. E. Smith, manager, Soil Conservation Service nursery, Woodward, Okla.



FIGURE 22.—A, Farmer-cooperator W. H. Hayes, of the Lincoln County Soil Conservation District in Oklahoma, utilized the aftermath from seed-production and hay crops of weeping lovegrass for fall and early winter grazing until wheat and rye pasturage became available. He found that milk cows eat the grass readily. B, Late-summer grazing of the recovery growth (10 to 12 inches) of weeping lovegrass, following the harvesting of seed and hay crops on Nicholson's seed farm, Orienta, Okla.

producing satisfactory year-to-year seed and hay crops, the latter being eaten readily by cattle and work stock.

A number of farmer cooperators of the Lincoln County Soil Conservation District in Oklahoma have utilized erosion-control plantings of weeping lovegrass for pasture and found that dairy cows and calves ate the grass readily and made very good gains (fig. 22). In reporting the results of his experience, Ralph Mehan, of this district, states: "I selected 5 bucket-fed calves (Hereford \times Jersey) averaging 177.2 pounds in weight that had been dropped in March and turned them on the lovegrass pasture the first of July. The grass,

seeded broadcast with a cyclone seeder the 26th of April, 1943 (the same spring) at the rate of 1 pound per acre, was 8 to 12 inches high and in good growing condition when the calves started grazing. The average daily gain per calf for July was 1.21 pounds and for August 0.82 pound, giving an average gain of a little more than 1 pound per day for the 2-months' grazing period."

A series of 14 organized farmer-cooperator utility trials of more or less uniform type were initiated in Oklahoma in the spring of 1941 by the Oklahoma Agricultural Extension Service, Bureau of Plant Industry, Soils, and Agricultural Engineering, and the Soil Conservation Service,²¹ in which weeping lovegrass was seeded as a mixture with the better locally native short grasses. The plantings were located in representative farming areas throughout the western half of the State on land that ordinarily is retired to pasture and were of field-scale size (5 to 25 acres).

Of the several grasses used in the mixture, the lovegrass and blue grama predominated. During the first year very little grazing was practiced. Subsequently, however, the grasses were pastured at various times, to various extents, and with various classes of livestock. In most instances, in addition to supplying good pasturage, the weeping lovegrass produced harvestable hay and seed crops the second season, which was not true of the native species.

During the late summer of 1942 J. E. Smith and the writer visited several of these plantings and made an initial evaluation of the weeping lovegrass as then reflected in the trials. Where the lovegrass consisted mostly of new growth not more than 10 to 12 inches high, it was being grazed by cattle and horses with apparent relish and the animals showed no evidence of discriminating in favor of the immediately adjacent native grama grasses. On the other hand, plantings composed largely of mature growth, as the result of not having been mowed or fully pastured, were not being grazed satisfactorily. The dissimilarity in growth habit and time of maturity of the lovegrass indicated that greater and more permanent pasture values might be obtained by growing it as pure seedlings and following the practice of intensive grazing during spring and early summer and then removing the stock in time for top growth to become fully restored by the end of the current growing season, thus utilizing the grass at its most nutritious stage and at the same time preventing its becoming weakened by overgrazing. Also, its tendency to dominate the shorter native grasses suggested a lower seeding rate than the 2 pounds per acre used in this instance. In general it was apparent that where grown with a full knowledge of its limitations as well as its good qualities, this grass held distinct advantages as a supplement to native-grass pasturage in a majority of the farming areas represented by these plantings.

Of the 14 plantings, that of Farmer-cooperator Eugene F. Nicholson, near Orienta, Okla., situated on rolling, eroded land that has been retired from regular crop production, is considered as repre-

²¹ These planting trials were planned by D. A. Savage, Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture; J. E. Smith, manager, U. S. Soil Conservation Service nursery, Woodward, Okla.; and H. C. Hyer, assistant extension soil conservationist, Oklahoma Agricultural and Mechanical College.

sending about the average. (See fig. 22, *B.*) In describing his experiences with weeping lovegrass, Mr. Nicholson said:

My cattle have pastured on this lovegrass for 2 years now and I can see no difference in their condition than when they pasture on native grass. I believe it will carry at least twice as many cattle per acre as any of the native grasses. From my 13-acre pasture the second year after seeding I cut 2 tons of hay per acre besides pasturing 10 head of cattle all summer. My young cattle and horses seem to eat the hay satisfactorily but, having been cut after wheat harvest, the growth had become tough and the older cattle would not eat it unless very hungry. Most cattle eat the hay readily during cold weather, and used in connection with wheat pasture or with cottonseed cake, it seems to make a very good dry feed.

Utilized primarily for revegetation purposes under range conditions in the semiarid Southwest, Lehmann lovegrass is proving a valuable supplement to native-grass pasture in the warmer parts of that section. Its value as a grazing grass is attributed mainly to early spring growth, the retention of green, succulent basal leaves and stems during fall and winter, and ease of establishment under severe conditions. These qualities, not so apparent in the native grasses, enable it to fill two very important gaps in range utilization—a period of 2 to 3 months in spring and early summer before the perennial native grasses have made much growth and a similar period in fall and winter after the native grasses have dried up.

A good example of Lehmann lovegrass complementing an individual native grass in season of usage is to be found in connection with the tobosa grass pasturage on the Walter Holland ranch near Paul Spur, Ariz. Only the fresh green growth of tobosa is grazed readily, and this does not appear until the midsummer rainy season. Using the contour-furrow method, Mr. Holland seeded the intermittently flooded, "slick" areas of his pasture where the tobosa had died out to Lehmann lovegrass, finding it suitable both for quickly revegetating denuded tobosa range and for carrying livestock during the spring months while the tobosa grass is still dry and dormant.

A 10-acre range pasture of Lehmann lovegrass established in 1938 near Sells in southern Arizona has furnished grazing for 10 mature cows at a production rate of 86 head per section on a year-long basis. In carrying capacity, this is an increase of 2,150 percent above that of the surrounding desert range.²²

EARLINESS OF GROWTH AND RECOVERY IN RELATION TO EROSION CONTROL AND FORAGE USES

The early, rapid growth of the lovegrasses enhances their value both for soil conservation and forage uses. This quality manifests itself not only in quick germination and emergence as seedlings, but in early spring growth, rapid recovery after mowing, grazing, or drought, and early maturity of the seed crop.

Weeping and Boer lovegrasses start spring growth about the same time, with the beginning of warm weather. This occurs generally from the middle to the last of February in the warmest sections and

²² E. L. Flory, regional chief, Soil and Moisture Conservation Operations, Office of Indian Affairs, Department of Interior, Phoenix, Ariz., in official correspondence.

TABLE 12.—Relative earliness and leaf-growth capacity of reaping foregrass and eight of the more common grasses¹

Species	March 29	April 5	April 12	April 19	April 26	May 3	May 10	May 17	May 24	Calculated weight per acre air-dried
	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Pounds
Weeping lovegrass (<i>Eragrostis curvula</i>)	2	3	4	4½	6	7	12	18	26	5,103
Sand lovegrass (<i>Eragrostis trichodes</i>)	1	1½	2½	3	3½	5	8	12	18	2,964
Blind guinea (<i>Bouteloua gracilis</i>)	—	1	1½	2	2½	3	5	7	10	2,408
Little bluestem (<i>Andropogon scoparius</i>)	—	—	—	1	2	4	7	11	14	3,152
Sweetgrass (<i>Panicum virgatum</i>)	—	—	—	—	2	6	9	13	26	3,501
Buffalo grass (<i>Buchloea dactyloides</i>)	—	—	—	—	2	3	4	5	6	1,020
Big bluestem (<i>Andropogon furcatus</i>)	—	—	—	1	3	5	8	12	18	3,804
Broomsedge (<i>Andropogon virginicus</i>)	—	—	—	—	1½	3	4	8	12	2,013
Bermuda grass (<i>Cynodon dactylon</i>)	—	—	—	—	2	4	8	12	16	2,115

¹Data were obtained from 3-year-old plantings at the National Observational Nursery, Beltsville Research Center, Md., in the spring of 1943. The old growth was cut back on March 15 to within 2 inches of the ground and measurements taken from that point.

correspondingly later as the northern limit of their range is approached. Lehmann lovegrass is about 10 days to 2 weeks later. In comparison with the more common grasses, the spring growth of weeping and Boer lovegrasses is 1 to 4 weeks earlier than most of the leading native species within their adaptation range as well as of that of many of the introduced species. Undoubtedly this highly desirable quality is attributable in large measure to the heavy crowns and root systems of these two grasses, which give them greater capacity for food storage, combined with the tendency toward continuous growth in the case of all three species. As has been previously indicated, in the warmer sections they do not become completely dormant during winter, their roots continuing active and their tops remaining green and making some growth during warm spells.

A series of observational studies was made at the National Observational Nursery, Beltsville Research Center, Beltsville, Md., during 1943 to obtain a more definite measure of the earliness and rapidity of growth of weeping lovegrass as compared with certain other grasses known to succeed within its adaptation range. Three-year-old, uniformly handled row plantings were utilized for the comparisons. Just prior to the beginning of spring growth, the growth of the preceding season was cut back to within 2 inches of the ground. This served as a definite point from which all measurements were made. Starting on March 29, the maximum growth of representative individual plants of each species was measured for a period of 9 weeks. The total amount of new growth was then removed and the calculated yield per acre obtained (table 12).

Similar data obtained the following year showed no appreciably different results. Both years the weeping lovegrass came out earlier in the spring, grew faster, matured more quickly, and produced greater vegetative growth within the same period of time than any of the grasses with which it was compared.

COMPARATIVE LEAFINESS OF THE LOVEGRASSES IN RELATION TO EROSION CONTROL AND FORAGE PRODUCTION

The amount of leaf growth in proportion to stem is an important consideration in evaluating a grass for erosion control as well as for forage uses. Tests to determine the relative leafiness of the three lovegrasses and how they compare in this respect with some of the more common grasses of somewhat similar growth habit were conducted at the National Observational Nursery, Beltsville, Md., during the summer of 1943. Big bluestem, little bluestem, switchgrass, and timothy were selected as the grasses with which the lovegrasses were to be compared. As the grasses reached maturity, the total current season's growth of representative 3-year-old individual plants grown under comparable conditions and taken to within 1 inch of the ground was collected, the seeding parts removed, and the leaf and stem growth carefully separated by hand. The average percentage of each is shown in table 13. It will be seen that weeping lovegrass is not only more leafy than the other two lovegrasses, but superior in this respect to the other grasses under comparison. Lehmann lovegrass is shown

TABLE 13.—Percentage of leaf to stem of weeping, Boer, and Lehmann lovegrasses and four common grasses of somewhat similar growth habit

Species	Age of plants	Leaves	Stems
	Years	Percent	Percent
Weeping lovegrass (<i>Eragrostis curvula</i>)-----	3	84	16
Weeping lovegrass (<i>Eragrostis curvula</i>)-----	1	81	19
Boer lovegrass (<i>Eragrostis chloromelas</i>)-----	1	66	34
Lehmann lovegrass (<i>Eragrostis lehmanniana</i>)-----	1	28	72
Big bluestem (<i>Andropogon furcatus</i>)-----	3	49	51
Little bluestem (<i>Andropogon scoparius</i>)-----	3	27	73
Switchgrass (<i>Panicum virgatum</i>)-----	3	57	43
Timothy (<i>Phleum pratensis</i>)-----	3	31	69

as the most stemmy of the lovegrasses. Although the proportions would be expected to vary somewhat under different growing conditions, they nevertheless are indicative of the relative effectiveness of these grasses in the control of erosion and the production of forage.

THE EFFECT OF SEVERE CLIPPING ON THE ROOT SYSTEM AND TOP GROWTH OF WEEPING LOVEGRASS IN RELATION TO EROSION CONTROL AND FORAGE AND SEED PRODUCTION

The fact is now well established that removal of an undue amount of top growth is at the expense of previously deposited food reserves and causes a weakening of the plant. Obviously, therefore, as found by Biswell and Weaver (6), Canfield (9), Harrison and Hodgson (22), and others, frequent and close clipping of the tops of a grass reduces the total top and root growth produced. Equally obvious, such treatment lessens proportionately the effectiveness of a grass when used for erosion control or forage.

The application of this principle to the lovegrasses is particularly significant. In weeping lovegrass, for example, although the heavy top growth and deeply penetrating root system of the mature grass improves its value as an erosion-control plant, the young, tender growth induced by mowing or close grazing is much more nutritious and palatable for livestock. Therefore the utilization of this and the other two species for soil conservation-forage purposes calls for managerial methods that insure maximum utilization without permanent injury to the grass.

These grasses have not been in use long enough in this country for appropriate mowing and grazing-management practices to be worked out. Realizing that the development of such practices is essential to their efficient use and that they must be based upon known responses of the plant to specific treatments, the author initiated observational tests in 1943 to determine the effect of different intensities of clipping upon weeping lovegrass as related to its use for soil conservation purposes. While the tests are not far enough advanced for full and final conclusions, preliminary observations on the effect of severe clipping on the root system and top growth are very significant.

The method used was that employed by Crider (12, 13), previously mentioned, in which the grass was grown in wooden-box containers provided with light-protected, glass fronts, and the responses of the roots to top removal carefully noted from day to day. The boxes were of two sizes—3 (width) by 20 (length) by 18 inches (depth), and 4 (width) by 20 (length) by 48 inches (depth), inside dimensions, with $\frac{1}{4}$ -inch holes and a 1-inch layer of pebbles in the bottom to provide drainage. The boxes were firmly filled with soil to within 1 inch of the top. To provide as uniform growing conditions as practicable, the work was done in the greenhouse, with the minimum-temperature control set at 68° F. Throughout the observational periods the containers were kept in a forward-tilted position of approximately 30°, which made at least 50 percent of the main roots visible from their early development stage until they reached the bottom of the boxes. Chinaware pencils, facilitated by the use of a reading glass, served to mark directly on the face of the glass the day-to-day rate of root elongation. The recording of root elongation, top measurement, and clipping was made at a definite time of day.

Three series of clipping tests were conducted. In the first series, three $3 \times 20 \times 18$ -inch boxes were used, and the grass started from seed. Planted $\frac{1}{4}$ -inch deep and about $\frac{1}{4}$ -inch apart along the upper face of the glass, the seed germinated within 5 days, and 5 days afterward the young seedlings were thinned to 7 strong individuals per box, spaced approximately 3 inches apart.

This series covered a complete growth cycle—seed planting to seed maturity—and consisted of simple clipping treatments as follows: Box *a*, unclipped as a check; box *b*, clipped twice to within 1 inch of the ground, practically all leaf surface being removed at the time of clipping and the top allowed to grow out to about its original height before the second clipping; box *c*, clipped to within 3 inches of the ground every other day (fig. 23). All clippings were retained and oven-dry and green weights obtained of root and top growth.

The first clipping was on October 16, 54 days after planting. At this time the plants in the three boxes, as indicated by their general appearance and as shown by detailed top and root measurements and culm and root counts, were comparatively uniform in size. The leaf growth averaged 11.20, 10.80 and 9.50 inches in length, respectively, per box. In the same order, the total number of vegetative culms per box were 88, 87 and 83, the number of visible main roots 71, 67, and 65, the number of roots in position to be recorded as elongating 21, 26, and 11, and the average rate of root elongation per 24-hour period 1.24, 1.30, and 1.20 inches, respectively (table 14). At least 50 percent of the visible main roots in each box apparently had reached the bottom.

Within 18 to 24 hours after the tops of the grass had been cut back, all visibly elongating main roots and laterals in boxes *b* (clipped to 1 inch) and *c* (clipped to 3 inches) ceased elongation. These roots not only failed to resume elongation, but soon lost their fleshy, sheath-like covering and vigorous appearance.

In the case of box *b*, evidence of renewed root activity did not oc-

cur until 16 days after clipping, after the leaves had reached an average length of 8.05 inches. Then four entirely new main roots were seen to have emerged from the crowns of three of the plants and there was evidence as well of renewed lateral root activity. New main roots continued to emerge from day to day and 33 days after clipping, with the leaves averaging 9.58 inches in length, the root systems of the plants in this box apparently were about restored. Visible at this time were 103 elongating main roots ranging in length from $1\frac{1}{2}$ to more than 16 inches. This was only 15 less than those of the unclipped box, but the latter had attained greater depth and were more branched. In top growth, the plants in box *b* produced almost as many new vegetative culms during this period as those in box *a* (unclipped), but the average height (not including the seed heads in box *a*) was 2.46 inches less.

At this point, 87 days after planting, or 33 days after the first clipping, the tops of the plants in box *b* were again clipped to within 1 inch of the ground. As when the plants were first clipped, all visibly elongating main and lateral roots ceased elongation within 18 to 24 hours after the tops were cut back. Varying in performance from the preceding, the nonelongating roots in this instance remained fleshy and whitish in appearance, and 5 days after clipping, a very small percentage (0.062 percent) resumed elongation. The growth of these roots, however, was weak and spindling, both the size and rate of elongation being less than half that of normal.

This retarded-growth condition lasted about 2 weeks, when there was a general development of laterals on both the older and newer roots in the lower half of the box, which continued with increased intensity. Then, 21 days after clipping, with the leaves averaging 6.15 inches in length, new main roots began to form on the crowns of the plants. Due apparently to slower top growth, these main roots were later in forming than after the initial clipping, but once started they grew equally fast and increased rapidly in number.

The plants in box *c* that were clipped to within 3 inches of the ground every other day showed no evidence whatsoever of renewed root activity until 40 days after the initial clipping. At that time 3 new main roots started from the crown of one of the plants. During the succeeding 5 weeks, until the close of the test, a total of only 33 visibly elongating main roots formed, and they were decidedly weak and spindling in appearance. Finally all except two ceased to elongate.

In the case of the unclipped plants in box *a*, root elongation was continuous throughout the growth cycle, including the period of seed ripening, with new main roots emerging almost constantly from the crowns. The roots continued in vigorous condition, retained their whitish, fleshy covering and maintained a consistently greater average daily elongation rate than those of the clipped series. Toward the latter half of the growth cycle, the main roots became so numerous and lateral formation so intense that it became difficult to differentiate between the newer and older roots.

In 127 days after planting, the growth cycle of the weeping lovegrass was complete, as indicated by the fact that the seed heads on the unclipped plants in box *a* had become fully mature. (See fig. 23, *A*.) At this point the glass fronts were removed from the boxes

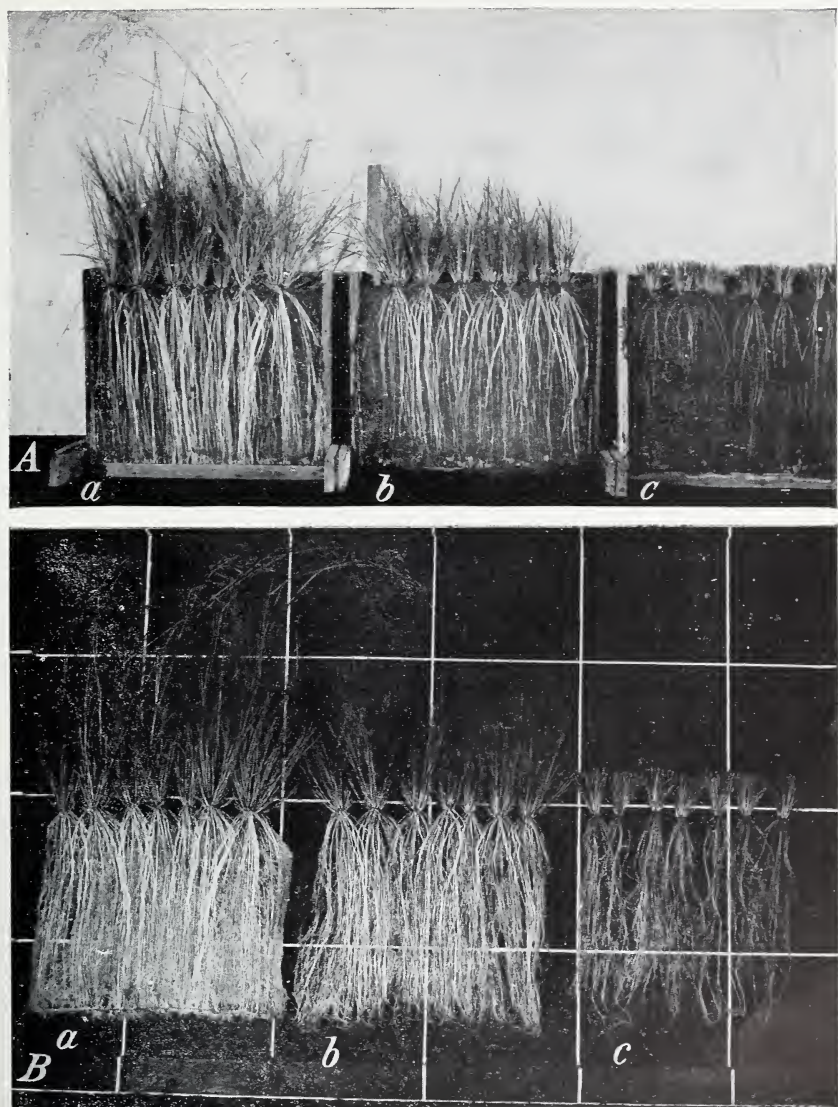


FIGURE 23.—A, The root and top development (127 days after seedling) of three differently treated groups of weeping lovegrass plants grown in glass-front containers. The plants in box *a* were allowed to develop normally. Beginning 54 days after seeding, the plants in box *b* were clipped twice within 1 inch of the ground at an interval of 33 days, and those in box *c* were clipped within 3 inches of the ground every other day. B, the same groups of weeping lovegrass plants after the glass fronts were removed from the containers and the roots washed free of soil. Note the much-lessened root development of the plants in box *b*, whose tops were clipped twice, and the extremely meager root development of those in box *c*, whose tops were clipped every other day, as compared with the heavy root development of the unclipped plants in box *a*.

and the roots washed free of soil. This was accomplished by holding the boxes in a tilted position and playing a fine spray of water on the root-soil mass. Due to the tenacity of the roots and the sandy nature of the soil, the loss of vegetative material by washing was negligible.

Cutting back the grass was found to have resulted not only in complete stoppage of root elongation for a period following clipping, but also to have influenced adversely the total yield, number, depth, and size of the roots, as well as the development and total yield of the tops (tables 14 and 15). Figure 23, *B* picturing the root system of the grass just after washing, shows something of the dissimilarity in root development of the three series of treatments. Differences in the density of the root mass is particularly evident.

The amount of root growth in the twice-clipped unit as expressed in oven-dry weights, was approximately 23 percent less and the one clipped on alternate days 90 percent less than the unclipped unit, and the difference in depth of rooting was almost as much at variance. Although distinctly marked, the reduction of total top growth caused by clipping was not so great as that of root development, being approximately 8 percent less for the twice-clipped unit and 34 percent less for that clipped every other day. As a supplement to the actual oven-dry weights, the differences in total root and top production as the calculated green-weight yields per acre also are given in table 15. These figures were reached by using 16 plants per square foot as the basis of calculation, which approximates the distance between plants in the box containers.

Upon final examination of the root systems of the three units, it was evident that only a limited number of the very immature roots had died from the effect of top-growth removal. The main roots, which during the course of the tests were observed to have stopped elongating shortly after clipping, showed that their growing points had become suberized and that subsequent branching had taken place. Apparently they simply remained quiescent for a period following clipping, until the top was sufficiently restored, and then resumed lateral growth. The resumption of lateral growth, as determined by day-to-day observations, coincided very closely with the periodic beginning of main-root elongation.

The tops of the plants of all three units retained their normal color and healthy condition throughout the growth cycle, and the unclipped plants produced well-developed seed heads. Breaking-point tests of the leaves at the end of the growth cycle showed those of the twice-clipped plants to be about 30 percent more tender than those of the unclipped plants.

The second series of clipping treatments was carried concurrently with the first and the same size box used, but it was handled differently. In this instance two plants only were grown in a container, transplanted as young seedlings 6 inches apart. After these plants became well established, with well developed tops and roots, one of them was clipped to within 2 inches of the ground, followed by 2 similar clippings at intervals of 1 week (fig. 24).

Roots of the unclipped plant developed and elongated constantly throughout the observational period, but those of the adjacent clipped plant not only ceased elongation when the tops were re-

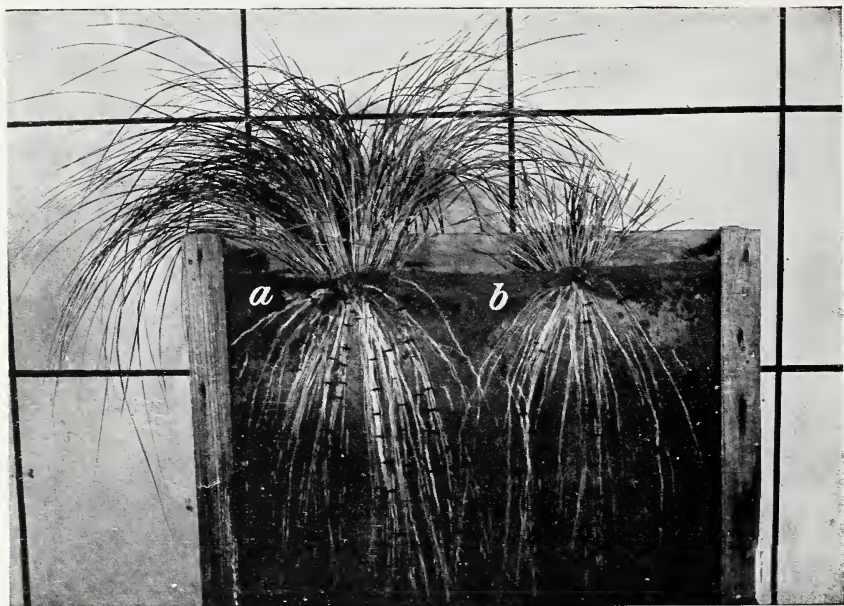


FIGURE 24.—Two typical first-year plants of weeping lovegrass showing stoppage of root development as result of severe clipping. The amount of growth made by the visible elongating roots of *a* and *b* was marked on the face of the glass when *b* was first clipped to within 2 inches of the ground. Four weeks later (when this picture was taken), following three additional clippings at 1-week intervals, the roots of *b* showed no further development while those of *a* had increased in number and continued to elongate.

moved, as in the case of the first series, but upon washing showed no indication of having made any growth since the initial clipping. This was evidenced by the fact that the tips of the roots had lost their whitish appearance and become suberized.

In the third series, the box having a depth of 4 feet was used in order to observe the effect of top removal at a lower level than was possible with containers only 18 inches deep. Two seedlings were grown 6 inches apart in this box and clipping delayed until the plants were 4 months old and had a large number of visibly elongating roots at the 3- to 4-foot levels (fig. 7). One plant was then cut back to within 4 inches of the ground. In less than 15 hours the roots ceased elongation, furnishing additional and apparently conclusive evidence that top removal causes the entire root system to stop growth. This fact, however, was further confirmed by growing artificially-fed seedlings in sphagnum moss in 6-inch pots until the moss became well filled with white growing roots and then lifting out the root mass and coating it with moistened carbon black. Plants treated in this manner and then cut back near the base showed no evidence of renewed root activity until 3 weeks later, after the tops had grown out 12 to 14 inches, when the first new, white root tips appeared in the blackened root mass.

These findings show that heavy top removal has a tremendous

effect in retarding root development, reducing top growth and generally weakening the plants. This was illustrated by the behavior of the grass clipped to 3 inches every other day from the time it was about 7 weeks old, somewhat simulating constant, close grazing. Not only was the production of above-ground parts too low for satisfactory erosion control or forage use (table 15) but, in density, strength and depth, the root systems were inadequate properly to hold eroding soil (fig. 23 *B*, *b* and *c*). Also, the shallowness and lessened vigor of the roots would subject them to greater injury from drought, winter cold, and other adverse conditions.

Correlated with the above observations, it was found under field conditions that reduction in seed and forage production, as well as injury from cold and drought, was in direct proportion to the number of mowings during the growing season. One mowing of 2-year-old seedlings in the spring after the new growth was 10 to 12 inches high (simulating one good grazing period) had no appreciable effect upon productivity during the current season, but two mowings at intervals of 3 weeks reduced the current seed and forage yields by approximately 50 and 12 percent, respectively. The subsequent unfavorable effect of top removal was evident by the fact that four mowings at intervals of 3 weeks, beginning the first of June, lessened next year's seed and forage yields about 80 and 40 percent, respectively, and five such mowings caused partial winter-killing, negligible seed production and serious weakening of the grass.

Similarly, it was observed that heavy, continuous grazing of well-established seedlings of weeping lovegrass throughout spring and summer, especially when associated with drought or a cold winter, had the effect of severely reducing the stand, as well as seed and forage yields the succeeding year. This, however, is generally true of nonstoloniferous grasses, and the fact that it applies even more aptly to some of our good native species was shown by the comparative effect of severe clipping upon big bluestem, switchgrass, little bluestem, and weeping lovegrass.

Beginning the first of May, well established seedlings of these grasses were cut back 4 times within 2 inches of the ground at intervals of 1 month and their condition noted the next year. All the grasses were greatly weakened, as evidenced by dead centers, reduced growth and less seed production, but the weeping lovegrass made by far the strongest recovery. Using the number of seed culms as a measure of their relative recuperative ability, the percentages less than normal were as follows: Big bluestem, 95 percent; switchgrass, 90 percent; little bluestem, 87 percent; weeping lovegrass, 20 percent.

Precisely how soon after planting, how often during the growing season, and how close these lovegrasses may be grazed or mowed without seriously injuring them or lessening their efficiency for soil conservation and for forage production must be determined by additional field trials related to local conditions. It has become clearly evident, however, that the development and maintenance of a deep, strong root system and hence a highly productive, permanent stand of grass is not possible if top growth is reduced by overgrazing or mowing beyond the point where it can be restored to normal before the end of the current growing season. In general, therefore, it would

be unwise to graze heavily or to mow new seedings the first year or to graze seedings of any age continuously and heavily throughout spring and summer. Considering the fact that these grasses are most palatable and nutritious while the growth is fresh and tender, it appears that greater pasture values can be obtained and with least harmful effect by utilizing them for grazing or hay during spring and early summer and during winter, where temperatures permit. This leaves the latter half of the growing season for the restoration of balance between the roots and tops and for the grasses as a whole to recuperate. Also, it appears that close grazing for short periods, with rests between each period, is better practice and less harmful than more lenient grazing and longer periods of usage.

As shown by comparative tests and the fact that by the end of the growing season leaf growth has completed its function of storing plant-food reserves in the roots and crown, late fall and winter grazing may be practiced where there is no danger from cold without in any way weakening these grasses or lessening their productivity during the succeeding growing season.

CULTURE

Weeping, Boer, and Lehmann lovegrasses respond readily to the cultural methods ordinarily employed in the growing of small-seeded farm crops. The fact that they are characteristically vigorous and fast-growing and not too fixed in adaptation requirements simplifies their establishment and subsequent care. Like most farm crops, however, the specific cultural demands of these grasses vary in large measure according to local conditions, such as climate, soil, and the purpose for which they are to be used.

Time of Seeding

Seeding tests have shown that shattered seeds of these lovegrasses will remain in good condition over winter and come up the following spring when conditions become favorable. With this as an indicator, it was found that they may be planted in the fall or before the end of freezing weather in the spring and good stands obtained. On the other hand, the seeds will not come up until the soil is thoroughly warm, and usually there is no advantage in planting before that time. The beginning of the planting season for these grasses, therefore, may vary from around the middle of February in the extreme south to as late as June near the northern limit of their adaptation range.

Seeding may be done in the warmer sections almost any time in spring and summer when moisture conditions are favorable, but in the colder, short-season areas early planting is advisable to obtain sufficient root and top development to prevent injury during the first winter. In general it is advisable to plant weeping and Boer lovegrasses as early as practicable to secure the greatest possible root and top development the first growing season as a guarantee of maximum seed and foliage production the succeeding year, and likewise Lehmann lovegrass to obtain the best yields during the current year.

In some of the warmer, drier areas planting time is regulated more by the prevailing seasonal rainfall than by temperature. Such a condition obtains over much of the Southwest. In that section where very little rain may be expected during the first few months of warm weather, it has been found best—unless irrigation is practiced—to defer seeding until the beginning of the mid-summer rainy season. Again, in the warm, winter rainfall belt of California the appropriate planting season is late fall at the beginning of the rainy season. The time of planting is influenced as well by other local conditions, such as the possibility of soil blowing, grasshopper damage, and annual weed infestation.

Seeds of most grasses have a period of dormancy after they are harvested during which maximum germination will not take place. In the case of weeping lovegrass, a high percentage of the seed is immediately viable and the maximum percentage about two months later. The after-harvest dormancy periods of Boer and Lehmann lovegrasses are considerably longer than that of weeping lovegrass. However, seeds of all three grasses produced one year usually give good stands the next.

Depth of Planting

Although the seeds of all three of these lovegrasses are very small, they differ appreciably in size (fig. 6), which fact is reflected in their depth-of-planting requirements. The seeds of weeping lovegrass are the largest, approximately $1\frac{1}{2}$ million per pound. Those of Boer lovegrass are about one-half and those of Lehmann lovegrass about one-fifth that size, or about 3 million and 7 million seeds per pound, respectively.

In usual farm and range operations, the response of the seed to soil coverage is influenced greatly by, and must be closely correlated with, local soil and weather conditions as well as cultural and erosion-control practices. Experience indicates that it is particularly important in regulating the depth of planting to take into account the possibility of wind or water action in either uncovering the seeds or covering them too deeply. In common with other farm crops, these grasses require deeper planting on light than on heavy soils and greater depth in dry, windy than in humid climates or where irrigation is practiced. At the same time, due to remarkable vitality and power of quick germination, the seeds will emerge under a comparatively wide range of soil depths, which has the advantage very often in shallow planting of enabling the seedlings to become established before the surface soil dries out and, on the other hand, permitting deep enough seeding for plant establishment under less favorable soil moisture conditions.

Under customary seedbed conditions, generally satisfactory germination and establishment have resulted from setting the opening plow of the garden-type seeder or the depth-rim of the drill seeder so as to leave the seeds (after the press wheel passes over them) covered to the following depths:

Weeping lovegrass	$\frac{1}{2}$ to $\frac{3}{4}$ inch
Boer lovegrass	$\frac{1}{4}$ to $\frac{1}{2}$ inch
Lehmann lovegrass.....	Surface to $\frac{1}{4}$ inch

There is no appreciable difference in the time of seedling emergence of the three grasses. If soil moisture and temperature are favorable, the seedlings will begin to come up within 3 to 4 days and reach a full stand about 6 to 8 days after planting.

Seeding Rates

The quantity of germinable seed used has been found a determining factor in the success and usefulness of a lovegrass planting. The growth, seed production and grazing qualities of weeping and Boer lovegrasses, and to a lesser degree Lehmann lovegrass, are influenced greatly by the rate of seeding. Normally, weeping and Boer lovegrasses make large, heavy clumps, and, due to the virility and smallness of the seeds, too heavy seeding is a common planting error. As observed generally, high seeding rates, which result in overcrowding and severe competition among the seedlings, have a marked effect in retarding the growth of the plants, diminishing the color and increasing the harshness of the leaves, lessening the seed crop, and reducing palatability. Also, where these vigorous, fast-growing grasses have been used in mixtures with other grasses, high seeding rates in some instances apparently have resulted in the suppression of some of the shorter, slower-growing species. On the other hand, it has been found that if seeded too lightly, they are proportionately less efficient in producing quick, effective ground cover, retarding runoff, holding back silt accumulations, and controlling sand blowing.

The seeding rate must be governed primarily by the germinable quality of the seed which, due mainly to weather conditions and errors of judgment as to the ripening period, may vary somewhat from season to season and in different sections. By first knowing the germination percentage of the seed, the number of seedlings desired per linear or square foot and in turn the poundage seeding rate per acre can be determined with reasonable accuracy.

Additional interrelated factors that influence the seeding rate are: (1) The intended utilization—water or wind erosion control, siltation barrier, soil building, seed production, forage; (2) method of planting—row, drill, broadcast; (3) site conditions—type and fertility of the soil, degree of slope, prevailing winter temperature, whether or not irrigation is practiced, preparation of seed bed; (4) composition—planted singly or in combination with other grasses or legumes. The seeding rates for the three grasses are about the same, and in comparison with most grasses and other small-seeded farm crops they are very low. Based upon the use of clean, viable seed and favorable planting conditions, the per acre seeding rates found generally satisfactory are as follows:

1. Row planting for water and wind erosion control, siltation, soil building, forage or soil conservation—forage usage—1 to 2 pounds.
2. Broadcast and drill planting for water and wind erosion control, siltation, soil building, forage or soil conservation—forage usage—2 to 3 pounds.
3. Row planting for seed production— $\frac{1}{2}$ to 1 pound.
4. Broadcast and drill planting for seed production— $1\frac{1}{2}$ to 2 pounds.
5. Mixture planting (legumes or grasses) depending upon the combination— $\frac{1}{4}$ to 1 pound.

The Seedbed

Seedbed preparation has become an intimate part of soil and moisture conservation practices. Without the employment of appropriate measures to prevent runoff on sloping lands, to control sand blowing in windy sections, and to permit better water penetration on tight soils, satisfactory plant establishment, stand retention, and normal vegetative growth and seed production usually are not possible. Therefore, while these lovegrasses will produce good stands and volunteer under conditions which are fatal to all but the most persistent and drought-hardy native grasses, they nevertheless respond favorably to the methods of seedbed preparation and associated conservation practices found suitable for the establishment of the more common grasses. These methods and practices vary widely according to local climatic and soil conditions.

In the semiarid Southwest, where soil moisture is the predominant limiting factor in securing stands of grass, a number of practices have been successfully employed, such as contour furrowing, ridging, diking and mulching, to hold the water on the land and thus create the proper moisture condition for seed germination and stand establishment. Numerous seeding trials have shown that the lovegrasses lend themselves to preplanting treatments of this kind. The contour-furrowing treatment and attendant soil conditioning have proved most generally satisfactory, however, under range conditions in that section in providing a suitable seedbed for these as well as other grasses. This method of erosion control-plant establishment was devised by technicians of the Soil Conservation Service to meet the peculiar problems of the Southwest.

While the methods of furrowing may vary according to local conditions and available operating equipment, there are two basic types: (1) Widely spaced contour furrows, consisting of large, deep, double furrows and (2) closely spaced contour furrows, consisting of single, shallow furrows.

The large, widely spaced contour-furrow preplanting treatment has been found particularly applicable to heavy, impermeable, sparsely vegetated soils that are subject to periodic flooding from runoff water. Under these semidesert conditions such bottom-land soils and some of the sparsely vegetated upland soils usually become sealed over, making the large deep furrow necessary in order to retard the large volume of runoff and allow time for complete infiltration. The method found most satisfactory in preparing this type of seedbed, especially in large-scale revegetation practices, has been to use a heavy, two-toothed subsoiler set at 12 to 18 inches with shovels attached to the shanks and pulled by a 20 hp. crawler-type tractor (fig. 25). Depending upon the character of the subsoil, a machine with similar shovels but without the subsoil teeth sometimes is used. Also, in the treatment of smaller areas, lighter furrowing equipment such as the disk plow, with less precise furrow spacing, has given satisfactory results.

The completed seedbed, with furrows 6 to 8 inches deep, 16 to 18 inches wide at the top, 5 to 6 feet apart and spaced at 20- to 30-foot intervals, allows for the accumulation of runoff from above the



FIGURE 25.—Two-toothed subsoiler preparing the double, widely spaced contour-furrow type of seedbed, found especially applicable under range conditions in the Southwest in revegetating heavy, impermeable soils that are subject to flooding. (Courtesy of C. B. Brown, County Agricultural Agent, Pima County, Ariz.)

furrows and its retention in the furrows, providing added moisture for germination and sustained plant growth (fig. 12, A).

The closely spaced, single, shallow contour-furrow pre-planting treatment has found its greatest use on the more permeable soils where the smaller furrows are adequate for rainfall retention. The furrows, 3 to 4 inches deep and 3 to 6 feet apart, are made by the single or multiple-row lister operated from a light tractor or horse-drawn equipment. This type of soil treatment controls runoff and provides moisture-accumulating depressions with minimum disturbance of the soil, which under semiarid conditions facilitates seed germination and stand establishment.

Much of the earlier contour-furrow seeding under range conditions in the Southwest was on unfirmed seedbeds. It has become increasingly evident, however, especially on the looser, more permeable upland soils, that a firm seedbed retains more moisture in the surface soil and results in consistently better stands. The use of the cultipacker appears to be the best means so far tried of firming both the shallow and the deeply furrowed seedbed.

In medium-rainfall areas that are subject to severe wind erosion, such as parts of the central and southern Great Plains, it has long been known that a noncompetitive vegetative cover is essential to the successful seeding of most small-seeded farm crops, and more recently this type of seedbed preparation has been found equally applicable to grasses (36). Coming up quickly and growing vigorously, the lovegrasses have proved less susceptible to sand blowing, ground surface evaporation and soil encrustation than many of the grasses, making the conditions for their germination less rigid. Nevertheless, for certainty of establishment under dry, wind-erosion

conditions they appear to require about the same initial seedbed preparation as other perennial grasses.

To provide a satisfactory noncompetitive vegetative cover, unless ample decaying weed growth is present, involves producing on the land one season in advance of seeding an annual fast-growing crop, such as Sudan grass or one of the coarser sorghums. The growing of a crop of this kind and the resulting residue, serves not only to protect the young grass seedlings against the damaging elements but assists materially in supplying the other requisites of a good seedbed—firmed soil, ample moisture and reasonable freedom from weed competition. The preparatory crop is close-drilled at a relatively high seeding rate and mowed shortly before the seed crop matures, leaving a stubble 8 to 12 inches high and allowing the clippings to remain on the ground. Left undisturbed until the following spring, when the grass seed is drilled directly into the stubble mulch (fig. 26), this type of cover and the associated stabilized soil condition provide the most suitable seedbed for these lovegrasses under severe wind-erosion conditions.

In sections of higher rainfall (from approximately the hundredth meridian east) and under irrigation, where the retention of soil moisture is not so critical a factor, seedbed preparation for these lovegrasses is much less complicated. This may be illustrated by the response of weeping lovegrass to various types of seedbed preparation in a field trial by the Arkansas Agricultural Experiment Station and the Soil Conservation Service conducted on the Northwest Arkansas Land Utilization Project, referred to previously, near Fayetteville, Ark. Six different seedbed treatments replicated three times and randomized were compared, as follows: (1) No preparation or seed coverage; (2) no preparation, brush-dragged after seeding; (3) spring-tooth-harrowed without covering seed; (4) spring-tooth-harrowed, brush-dragged after seeding; (5) plowed and worked up with spring-tooth harrow, seed not covered; (6) plowed and worked up with spring-tooth harrow, brush-dragged after seeding.

Establishment and growth were satisfactory on all types of seedbeds except the one with no preparation and the one with no preparation other than brush-dragging after seeding. It was especially noticeable that the grass on land that had been spring-tooth-harrowed only was as good as where the land had been plowed and worked up with a spring-tooth harrow afterward; also, covering the seed by brush-dragging, as compared with no covering on cultivated ground, did not improve the stand.

A method of seedbed preparation that has given excellent results on soils that are not too heavy in the sections of higher rainfall is to rough-plow or disk the ground some weeks in advance of the planting season; then, after the first crop of weeds appears and just prior to seeding, to surface-harrow and cultipack. A common practice is to cultipack before seeding and again at right angles to the first operation after seeding, or during seeding if a cultipacker-seeder is used. The depressions left by the wheels of the cultipacker operated on the contour retard runoff and facilitate moisture retention.



FIGURE 26.—A, Drilling weeping lovegrass and a mixture of native-grass seed into noncompetitive, protective sorghum-stubble cover under severe wind-erosion conditions, Elkhart Land Utilization Project, Morton County, Kans.; B, the same 200-acre field, taken a month after seeding, shows the larger, more rapid growth of the weeping lovegrass that has already provided quick erosion-resisting soil cover and additional protection for the five slower growing native species in the mixture.

Farmer cooperators in central Oklahoma have found it practicable to use the same methods of seedbed preparation for weeping lovegrass as those employed in growing the small grains.

Planting Methods

All three of these lovegrasses may be grown as row or close-planted crops; but, requiring more space for development, weeping and Boer lovegrasses respond especially well to row culture while Lehmann lovegrass, owing to its layering habit, lends itself to close planting. No one method of planting is generally applicable to these grasses. Whether or not a particular species is row, drill or broadcast-planted depends mainly upon the locally suitable soil and moisture conservation practices, condition of the seedbed, character and fertility of the soil, and the purpose for which it is grown.

The seeds of the lovegrasses are too small to be planted with ordinary farm seeders. The garden-type seeder has proved the most generally satisfactory machine for handling them, operated either independently or mounted on other farm equipment. The adaptiveness of the garden-type seeder is such that it can be used for both row and close planting. As usually equipped, however, most makes of garden planters have proved inadequate for the very low seeding rates sometimes required in growing these grasses, more particularly for seed production. Technicians of the Soil Conservation Service overcame this difficulty by drilling smaller openings in the standard seed plate or by making an entirely new plate with smaller openings. Some manufacturers of seeders supply blank plates for such a purpose.

The fact that the seeds of these grasses vary slightly in size according to local growing conditions, as well as between themselves, makes it difficult to design a seed plate that under all circumstances will sow precisely the same amount of seed. As an indication of the size holes required, a single $3/32$ -inch opening will give for weeping lovegrass on 3-foot rows a seeding rate of approximately 1 pound per acre. Forty-two-inch row spacing would reduce the seeding rate to about $3/4$ pound per acre. The same size opening and row spacing would give slightly greater seeding rates for Boer and Lehmann lovegrasses.

The common grain drill may be used with a fair degree of success in close planting these lovegrasses by mixing the seed with a non-abrasive filler such as sawdust to prevent too high seeding rates. In planting lovegrasses in mixtures with larger or fluffy-seeded grasses or legumes, best results have been attained by broadcasting the lovegrass seed prior to drilling in the other seeds, as the small, clean lovegrass seeds settle out of a mixture of that kind and cause irregular stands.

The whirlwind type of hand seeder has proved satisfactory for broadcast seeding these lovegrasses, as with a little practice it can be regulated to sow almost any quantity of seed desired. Where seed is sown directly from the hand, however, it is helpful to mix a heavy filler, such as fine clean sand, with the seed in order to avoid too high seeding rates and to obtain uniform distribution.

The influence of local conditions upon planting practices is well



FIGURE 27.—Cultipacker-seeder made by mounting four seed hoppers of a garden-type seeder on 8-foot tandem cultipacker and found especially applicable to loose, permeable soils. The seed drop into the grooves made by the front cultipacker wheels and are pressed into the soil by the rear wheels.

illustrated by the variability of seeding methods found applicable in the regions of low rainfall. Here, in the intensely cultivated, irrigated valleys, these lovegrasses have been satisfactorily row- and close-planted with the garden-type seeder by seeding on smooth, firm, moist seedbeds at sufficient depth for the grasses to come to a stand before irrigating. Good results also have been obtained by irrigating the grasses up, using little or no covering and watering sufficiently often to prevent the soil from baking and drying out before germination takes place. The latter method of planting entails, in addition to a smooth, firm seedbed, making shallow (3 to 4 inches deep) surface corrugations—36 to 48 inches apart for row planting and 12 to 18 inches apart for broadcasting seeding. In row planting, the foot of the garden planter is removed and the seed sown in the bottom of the freshly-made corrugations with no covering except from the concave rear wheel of the seeder, while in broadcast planting the seed usually is left uncovered. The small corrugations facilitate even distribution of the irrigation water and the retention of surface moisture.

In contrast, much of the semiarid range land is rough and brushy. For this reason, as well as on account of essential associated soil and moisture conservation practices, the use of planting machinery is precluded and broadcast seeding is therefore necessary. However, on the more open areas as well as on abandoned croplands, where machinery can be used, the cultipacker has proved one of the most practical tools for planting, operated either singly after broadcast seeding or with garden seeder attachments. In range seeding trials in southern Arizona, good stand establishment of Lehmann and Boer

lovegrasses was obtained on permeable upland soils by the use of this type of seeder, following shallow, closely-spaced furrowing.²³ An ordinary 8-foot tandem cultipacker was used except that the wheels were set to track each other. Then, by mounting four garden-type seed hoppers on the cultipacker in such manner that each hopper had four delivery channels and dropped the seed between the sets of wheels, the seed was pressed firmly and evenly into the ground along with the general firming operation (fig. 27).

Under sandy, wind-erosion conditions where drill seeding is necessary in order that the seed may be properly placed with relation to soil moisture and noncompetitive vegetative cover, the garden-type seeder mounted on a grain drill has given good results. An assembled seeder of this kind is rendered more effective if provided with double-disk openers to each side of which has been attached edge-wise a narrow rim of steel to insure uniform planting depth and firmed soil.

In regions of higher rainfall the garden-type seeder, with or without the modified seed plate, depending upon the thickness of stand desired, has proved generally satisfactory for both row and close planting operations. Also, as in the drier areas, this type of seeder mounted on the cultipacker or grain drill has given good stand establishment.

A simple attachment (fig. 28) has been devised,²⁴ for use inside any planter box equipped with flat seed plates, by means of which lovegrasses can be satisfactorily seeded at low rates (patent applied for). It consists of a small funnel braced at the top and bottom of the box, a hollow "dog," which fits into the lower end of the funnel, and a steel spring, which holds the dog against the seed plate. The seed plate, obtained as a blank, is bored with holes of the appropriate size and number. This attachment may be made, and the plate drilled, in any small machine shop.

The seeding rate is determined by the size and number of the holes in the plate and the rate of turning of the plate, which is governed by the circumference of the drive wheel (not by the speed at which the tractor moves). For example, a 6-hole plate operated from a drive wheel 14 feet and 7 inches in circumference gives 9 drops of seed for each revolution of the drive wheel, or for each 14 feet and 7 inches of row. This combination of seed plate and drive wheel, as determined by tests with seed produced at the San Antonio, Tex., nursery, gives seeding rates at 3-foot row spacing as follows:

	<i>Opening Inch</i>	<i>Rate per acre Ounces</i>
Weeping lovegrass	4/32	8
Do	5/32	10
Do	6/32	16
Boer loveglass	5/32	12
Lehmann lovegrass	3/32	6

²³ E. L. Beutner, project supervisor, Soil Conservation Service, Tucson, Ariz., in official correspondence.

²⁴ By David H. Foster, manager, Soil Conservation Service nursery, San Antonio, Tex.

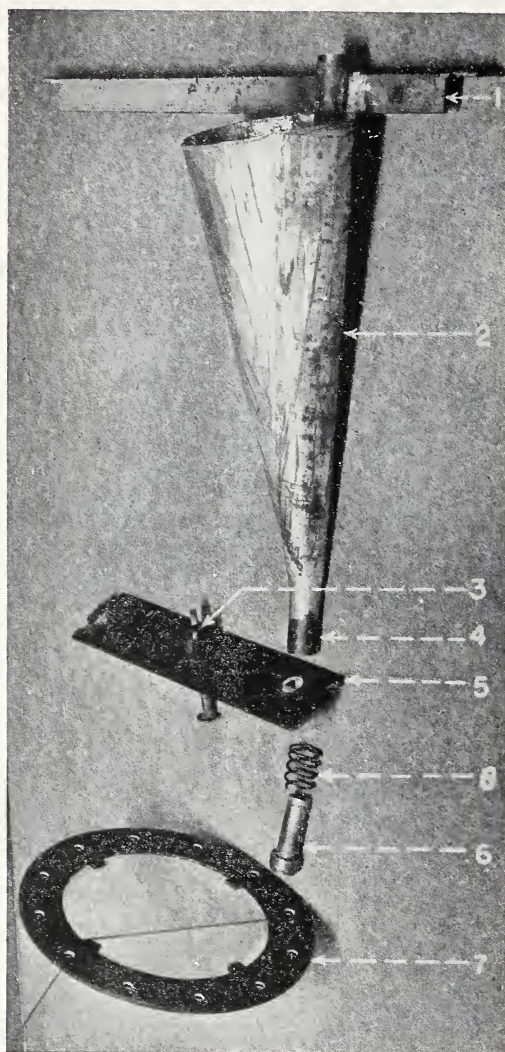


FIGURE 28.—Planter attachment for planting small seeds: (1) Bar to fasten attachment to top of planter box; (2) funnel for seed; (3) wing nut and bolt, which hold bar 5 in place at bottom of planter box; (4) nose of funnel, made from $\frac{1}{2}$ " pipe reamed to $\frac{5}{8}$ ", which rests on bar 5 and fits over dog 6; (5) flat bar 2" wide with $\frac{5}{8}$ " hole at right end, $\frac{1}{4}$ " hole in center, and $\frac{1}{4}$ " notch at each end, which fits in bottom of planter box to hold funnel and dog rigid; (6) dog made from $\frac{5}{8}$ " x 2" steel bolt drilled through center with $\frac{3}{8}$ " bit; (7) seed plate; (8) spring, which fits under bar 5 and over dog. Seed passes from funnel through dog to holes in plate.

Transplanting

Attributable mainly to their heavy basal growth is the fact that weeping and Boer love-grasses, and to a lesser degree Lehmann love-grass, may be transplanted readily either as young seedlings or as divisions of older plants. The size of the clump used in transplanting may vary from a single seedling or rooted division of the older plant up to as large a clump as is practicable for convenient handling. The use of parts of the older plant is facilitated by the fact that the crown is composed of a large number of rooted, vegetative culms that may easily be separated into any desired size. Usually these culms send out roots within a few weeks after they form on the mother plant and upon being separated and transplanted under favorable conditions, start new growth quickly.

Transplanting may be done with success in the warmer sections any time during the growing season when soil moisture conditions are favorable, but in the more severe climates there is danger of late summer transplants being winter-killed before they become well established.

The transplants are commonly row planted with the distance between rows and the spacing within the row de-

terminated by the purpose for which the grass is to be used. For seed production, 36- to 42-inch rows with the clumps set 12 to 15 inches apart in the row has given excellent results. On the other hand, where erosion control is the primary objective, the spacing must be close enough for the grass to form a continuous vegetative barrier.

The methods of transplanting commonly used for crops such as sweetpotatoes, tomatoes, and celery have been found applicable to these grasses, and the operation may be performed either by hand or by transplanting machinery. A simple method of transplanting, especially with larger plant divisions, is to furrow out the ground, drop the plants in the bottom of the furrow with the tops leaning to one side, cover the roots by running a second furrow beside the first, and firm the soil by cultipacking, rolling, or stepping beside each plant. Before transplanting, the tops of the plants are cut back to about 6 inches and straggling roots shortened.

Farmer cooperator A. H. Legago, of Wellston, Okla., described his experience in transplanting weeping lovegrass as follows:

I had 2 acres of poor, upland sandy soil upon which nothing would grow; and having heard of weeping lovegrass through my Soil Conservation District work, I obtained from the Soil Conservation Service nursery near Muskogee a truckload of this grass that had been plowed up and planted it in 36-inch rows on this 2-acre field. The planting was made May 2, 1942, by dividing the old crowns of the plants into small pieces about the size of one's thumb, similar to setting out sweetpotato plants. I cultivated the grass twice and harvested a seed crop July 8.

The fact that lovegrass may be transplanted easily has distinct advantages in soil conservation practices in providing a ready means of quickly controlling soil washing and siltation on critical areas. Frequently it is almost impossible to start vegetation from seed on freshly made banks, waterways, or other erosion-control structures because of the danger of the seed or young plants being washed away or covered by silt before they become well established.

Fertilization

Whether or not lovegrasses should be fertilized may depend both upon the use to be made of them and the fertility of the soil. Utilized as erosion-control grasses, they will become established on poor sites, but where the land is somewhat sterile, as in the case of raw clay subsoils, an application of fertilizer at the time of seeding has been found necessary to give them a good start and hasten ground coverage. Grown on the average soils, either independently or associated with soil-conserving practices, they usually must be fertilized in order to produce satisfactory year-to-year seed crops or high-quality forage.

It is commonly understood that the character of the soil may have a marked influence upon the grazing quality of a grass. As pointed out by Miller (29), the amount of any element that is found in the plant is influenced by the abundance of that element in the soil. Accordingly, if a soil becomes deficient in an important element the

deficiency is reflected in lowered palatability and food value of the grass. As previously indicated, it has been found that these lovegrasses have ample capacity for extracting from the soil and storing up the major quality-determining elements and that, utilized at the proper growth stage, they have relatively high food value and palatability. It is evident, therefore, that they are no exception to the general rule that the best seed production and feeding values come from the application of fertilizer in kind and amount necessary to supply existing plant-food deficiencies and maintain pasture grasses in thrifty condition.

The need for additional plant food is easily detected in these lovegrasses, not only by decreased seed and forage production, but by a yellowing and toughening of the leaves. Their response to quickly available fertilizer is even more striking, a greening up of the leaves and increased growth and succulence having been observed to take place very soon after the application is made. While the relative amount of the major fertilizing elements to be applied must be determined by local soil conditions, it has become apparent that, like most grasses, they respond favorably to fertilizers high in nitrogen and phosphate, especially the former.

The application of 200 pounds per acre of 6-6-5 fertilizer to weeping lovegrass at the time of planting was found to be the determining factor in obtaining a quick, well-established ground cover on a badly eroding, infertile slope at the Beltsville Research Center. In like manner, a top dressing of the same fertilizer at the rate of 500 pounds per acre on a thick broadcast, second-year seeding of this grass on poor sandy soil just preceding spring growth had the effect of producing 229 pounds of seed and 7.84 tons of green top growth per acre (at the time of seed harvest) as against no seed production and less than 1 ton of top growth on an immediately adjacent, unfertilized part of the field. Important also was the fact that the leaf growth of the fertilized portion of the field was green, succulent, and suitable for grazing, while that of the unfertilized area remained brownish, tough, and unpalatable.

SEED PRODUCTION

Under favorable conditions these lovegrasses are prolific seed producers. Normally, after becoming well established, they make two seed crops a year, a heavy crop in early summer and a light crop in late summer or early fall. The interval between the first and second crop is about 8 to 12 weeks. Planted early, weeping and Boer lovegrasses often produce light seed crops the first year after planting, but ordinarily very little seed may be expected until the second year. On the other hand, Lehmann lovegrass may be counted upon to produce at least one good seed crop the first year.

Although they are easily grown for seed purposes, their requirements for producing consistently heavy seed yields are rather exacting. Weeping lovegrass and Boer lovegrass, being so much alike in growth habits, present about the same production problems. First, the soil must be reasonably fertile or the lack of fertility must be compensated for by the use of fertilizer—a moderate top dressing

of nitrogenous fertilizer (25 to 30 pounds per acre of actual nitrogen) about the time spring growth starts has been found to have a remarkable effect in increasing the yield and improving the quality of the seed as well as promoting evenness of seed-culm development and ripening. Second, because these grasses form heavy clumps with proportionately large capacity for food storage, which apparently is needed for normal seed-culm development, they usually produce larger yields and better quality seed from row planting at comparatively low seeding rates. Third, close grazing or heavy hay production during the latter half of summer, after seed harvest and preceding fall dormancy, must be avoided in order to maintain sufficient leaf growth to build up plant-food reserves for the next year's seed crop. Fourth, having served its function of restoring utilized plant food, the old accumulated leaf growth and stem growth must be removed before or about the time spring growth starts—mowing or grazing-off the preceding year's growth having been observed to increase seed production by as much as 50 percent. Fifth, as plantings show evidence of deterioration, they must be renovated by between-the-row subsoiling, fertilizing, or cultivation, or a combination of two or all of these practices, depending upon local conditions.

The favorable effect of the application of fertilizer upon seed production of weeping lovegrass was strikingly demonstrated on infertile Plainsfield soil at the Allegan, Mich., nursery. A portion of a 2-year-old planting was fertilized with a 10-9-16 fertilizer at the rate of 600 pounds per acre and the remainder left unfertilized. The fertilized part of the field produced a dense stand of well-filled, evenly ripened seed heads that stood waist to breast high, while the adjacent, unfertilized portion developed only scattered seed heads, not heavy enough to warrant harvesting.

In field trials at the Beltsville Research Center during the summer of 1944, the fertilization of weeping lovegrass combined with the removal of the currently matured top growth following the harvesting of the midsummer seed crop stimulated seed-culm development and the production of a second seed crop equal to or greater than the first on land that ordinarily will produce but one light crop annually. Half of a 3-year-old planting on poor sandy soil that produced 98 pounds of seed per acre at the first harvest was mowed shortly after combining and a top dressing of ammonium sulphate applied to both mowed and unmowed areas at the rate of 200 pounds (41 pounds of actual nitrogen) per acre. Calculated upon the basis of seed-head counts, randomized and replicated five times, the seed yields resulting from these treatments were as follows:

1. Unmowed and unfertilized area—no seed production.
2. Unmowed and fertilized area—17 pounds per acre.
3. Mowed and unfertilized area—3½ pounds per acre.
4. Mowed and fertilized area—113 pounds per acre.

The next spring these test areas were mowed and fertilized uniformly with a 10-6-4 fertilizer at the rate of 400 pounds per acre. Succeeding midsummer seed yields were (1) 275, (2) 401, (3) 341, and (4) 341 pounds per acre, respectively. However, the ultimate response of weeping lovegrass to a continuance of the practices of spring and summer mowing and fertilizing remains to be determined.

In contrast to the other two grasses, Lehmann lovegrass produces good seed crops on comparatively poor soils, makes heavier yields if grown in thick stands, and does not require severe year-to-year top-growth removal to stimulate the formation of seed culms and increase seed production. Also, on account of its tendency to form solid stands irrespective of method of planting, this species does not lend itself to renovation except by top-dressing fertilization, and upon becoming deteriorated or badly infested with weeds it had better be plowed up and a new stand established.

In the case of weeping lovegrass, it is apparent that the production of seed culms and consequently seed yields is inhibited by a combination of high atmospheric humidity and high temperatures as light yields have been reported from southern Florida and southern Texas. On the other hand, consistently good seed yields have been obtained in the Southwest, where high summer temperatures and low humidity usually prevail during the development of the first and main seed crop. Likewise, good yields have been secured in the humid, cool climate of the northern Pacific coastal areas.

Atmospheric conditions appear also to affect the second seed crop of all three species. For example, in the Southwest, where the first seed crops usually are very heavy, they set poor second crops if the seed is allowed to mature during the extremely hot, humid weather of late summer. While it has been found possible to overcome this difficulty by cutting back the aftermath of the first seed crop so as to delay the ripening period until the cool weather of early fall, this practice is questionable because of the weakening effect of top removal at this season and the possibility of lessening the succeeding seed crop unless compensated by fertilization.

Ripening of the Seed Crop

Starting vegetative growth exceptionally early in the spring, these lovegrasses mature their seeds correspondingly early. Boer lovegrass is the first to ripen, putting up its seed heads and maturing 3 to 4 weeks ahead of weeping lovegrass. The time of ripening of weeping lovegrass varies from early June in the warmer sections to the middle or last of July near the northern limit of its adaptation range. The ripening season for Lehmann lovegrass is about 2 to 4 weeks later. The rapidity with which these grasses develop seedstalks and mature their seed is seen in the performance of a 2-year-old field of weeping lovegrass at the National Observational Nursery, Beltsville Research Center, Beltsville, Md., in 1943. The planting was on sandy loam soil, and just 38 days after the first seed heads appeared, the seed was fully ripe and ready to harvest. The effect of local soil conditions upon ripening was evidenced by the fact that on low, heavier soils in the same field the seed ripened 10 days later.

The general appearance of the grasses, combined with frequent examination of individual seed heads, seems the best means of determining when the seed crop is ready to be harvested. Unlike the small grains, in which the whole plant turns yellow by the time the seed is ripe, the lovegrasses ripen their seeds while the leaf growth and most of the seedstalk are still green. Beginning with the seed head, however, the degree of maturity of the seedstalk is definitely indica-

tive of seed ripeness. The seed head starts to ripen at the tip, with the ripening process continuing downward to the base. It takes about 8 to 10 days for weeping and Boer lovegrasses to become fully ripe and about 12 to 14 days for Lehmann lovegrass.

Day-to-day observations have shown that when the seeds near the tip of the seed head become ripe and brownish in color those near the midsection are immature and whitish and those at the base are just beginning to form. Some 5 to 6 days later the seeds in the midsection will have become ripe and brownish in color, and whitish, immature seeds will have developed in the basal portion of the seed head. Within 5 to 6 days more, these last-formed basal seeds also will have ripened and become brownish in color, thus concluding the ripening period.

Depending somewhat upon weather conditions, ordinarily there is a period of about a week to 10 days when seed crops of weeping and Boer lovegrasses may be harvested with comparatively little loss from shattering. Lehmann lovegrass, being less subject to shattering, may be harvested over a period of 2 to 3 weeks.

The seeds usually begin to drop as soon as the tip of the seed head becomes ripe and dry and the rate of shattering increases as it matures. If the seed head is allowed to become overripe, the seed shatters badly, especially during dry, windy weather, necessitating constant watchfulness in order to catch it at just the proper stage for harvesting. Therefore, with the first evidence of ripening, there is need to start examining the seed heads individually every few days by removing a head here and there over the field and rubbing parts taken from the tip, center, and base in the palm of the hand. When ripe, the smooth, dark-brownish seeds separate readily from the shuck. The maximum quantity of sound virile seed is obtained by harvesting as soon as the majority of the seeds in the lowest whorl of the seed head have lost their whitish appearance and become light brownish in color. To wait until all of the seeds in the lowest portion of the seed head are fully ripe will allow too much shattering to take place at the tip.

An observational study of the relationship of seed-head and seed-stalk development and maturity to the ripening and shattering of weeping lovegrass at Beltsville, Md., during the summer of 1943 showed results as follows:

June 1. Seedstalks emerging from crown of plants.

June 15. Seedstalks attained maximum height, 4 to 5 feet.

June 29. Seedstalks fully mature with seed heads assuming a creamy-brown color and beginning to droop at the tip. Seeds at the tip of seed heads ripe and brownish in color; those in the midwhorl immature and whitish. Basal portion of seed heads in flowering stage.

July 4. Upper one-third to one-half of stem of seed heads deep yellow in color, with tip beginning to dry; remainder light yellow in color. Seed in midwhorl of seed heads brownish in color; those in basal whorl mostly immature and whitish.

July 9. Upper one-third of stem of seed heads dry and distinctly drooping; remainder deep yellow in color. The majority of the seeds in basal whorl of seed heads, like those at the tip and middle, brownish in color. They are so crowded together that many are clearly visible on the outside of the seed-bearing parts. (A seed head of average size taken at this stage and lightly covered with soil in the greenhouse with the seed intact produced 454 vigorous seedlings.) Evidence is conclusive that the seed crop is at its peak and ready for harvesting. Loss from shattering through this stage, 1 to 3 percent.

August 1. Entire stem of seed heads dry, with yellowing of seedstalks extending to uppermost nodes. Loss from shattering through this stage, 22 days after being ready to harvest. 24 to 40 percent.

August 15. Seedstalks dry to the uppermost node. Tips of seed heads beginning to disintegrate. Loss from shattering through this stage, 37 days after being ready to harvest. 50 to 75 percent.

September 1. Seedstalks dead-ripe all the way to crown of plant. Loss from shattering through this stage, 85 to 90 percent.

The shattering rates given above were obtained by placing tar paper around typical 3-year-old plants in such a manner that all the seed that dropped could be collected and weighed against the total amount produced, supplemented by collecting a definite number of seed heads at the different stages of maturity at random throughout the field and making the calculations on the basis of the known average number and weight of the seeds contained in typical, unshattered seed heads.

The planting was on well-drained, sandy loam soil and the weather for the most part unusually dry, clear and warm except during the 10-day ripening period, which was quite cool (average minimum temperature, 53° F., maximum 81° F.) with 6 cloudy days. It is believed, however, that the length of the ripening period and the degree of shattering obtained may be considered as reasonably typical of what might be expected under average field conditions. They serve especially to emphasize the importance of being on the alert during the seed-development period, in order to avoid undue shattering, as well as harvesting before the bulk of the seed crop is mature.

Lehmann lovegrass shatters less readily and Boer lovegrass more than weeping lovegrass.

Seed Yields

Like most grasses grown for seed purposes, the yields per acre of these lovegrasses have been found to vary greatly with local conditions, more especially soil fertility and available moisture. The longest continuous seed-production record of either of them on the same piece of land in this country is that of the original field-scale planting of weeping lovegrass at the Tucson, Ariz. nursery. Established in 1936 in 3-foot rows partly from seed and partly from seedling transplants, this 15-acre planting has produced year-to-year average yields per acre as follows: 1936, 95 pounds; 1937, 281 pounds; 1938, 495 pounds; 1939, 460 pounds; 1940, 334 pounds; 1941, 271 pounds; 1942, 530 pounds (fig. 29).

The cultural treatment given this planting has been unusually simple and inexpensive. Other than irrigation and harvesting, the only regular cultural treatment found essential after the grass became well established was the prevention of year-to-year accumulations of vegetative growth by annually winter-grazing or spring-mowing the heavy aftermath. It was noted, however, after a few years that the colloidal character of the soil, together with noncultivation, had acted to retard water penetration and reduce seed production, making between-the-row subsoiling necessary. After this operation during the dormant season of 1941-42 the yield per acre, as will be noted above, almost doubled. The generally consistent



FIGURE 29.—The original field-scale planting of a 15-acre field of weeping lovegrass just before seed harvest at the Soil Conservation Service nursery, Tucson, Ariz.

heavy yields without cultivation or the application of fertilizer is attributed mainly to the use of sewer water for irrigation and the fact that the planting is on good river-bottom land.

The results obtained at the Albuquerque, N. Mex., nursery are more indicative of the seed yield of row-planted weeping lovegrass under average irrigated farm conditions in the Southwest. A 28-acre, 3-foot row planting (without fertilizer) on sandy loam soil of ordinary fertility during the first year after planting produced an average yield per acre of 50 pounds and during the second year 236 pounds. That soil fertility is a strongly determinative factor in seed yields was indicated by the fact that during the second year 7 acres of the better land in this field produced an average of 484 pounds per acre.

A good comparison of the yields of weeping lovegrass under irrigation and dry-land conditions in the medium-rainfall belt are the results obtained at the Woodward, Okla., nursery where the yields from established plantings under irrigation ranged from 320 pounds to 450 pounds per acre, and without irrigation, from 60 to 140 pounds.

A summary of seed-production records of weeping lovegrass generally show 250 to 300 pounds as about the average yield per acre on the better farm lands, with 400 to 500 pounds under the most favorable conditions. However, on the poorer, badly eroded soils yields of 50 to 100 pounds per acre are the highest secured.

Under comparable growing conditions, Lehmann lovegrass has been found to have about the same seed-production capacity as weeping lovegrass. Grown on good soil and irrigated with sewer water, the original field scale planting ($3\frac{3}{4}$ acres) started from transplants on 3-foot rows at the Tucson, Ariz., nursery in the spring of 1936, produced average yields per acre over a 6-year period as

follows: 1936, 490 pounds; 1937, 580 pounds; 1938, 242 pounds; 1939, 425 pounds; 1940, 272 pounds; 1941, 267 pounds. The lowered production during the last 2 years is attributed to the encroachment of Bermuda grass which often occurs with uncultivated crops on river-bottom lands in that section. Yields under average farm conditions, with irrigation or where rainfall is ample, have ranged from 100 to 250 pounds per acre, and under range conditions during good rainfall years about 40 to 50 pounds.

It has become increasingly apparent that on land that is not foul with weeds, so that cultivation is not needed, Lehmann lovegrass will produce higher seed yields the first year from broadcast planting than from row planting. Subsequently, after there is time for self-seeding to take place between the rows, the difference in seed production of row and broadcast seeding is negligible.

Yield records of Boer lovegrass indicate that the seed-production capacity of this species is considerably less than that of the other two lovegrasses. The original field scale seeding, row-planted at the Tucson, Ariz., nursery in 1936 under conditions similar to those for the other two grasses, has shown average yields per acre over a 4-year period as follows: 1936, 80 pounds; 1937, 239 pounds; 1938, 85 pounds; 1939, 313.5 pounds. At the Albuquerque, N. Mex., nursery on light soil of low fertility a 6½-acre seeding failed to set seed the first year, but produced 31 and 114 pounds per acre, respectively, the second and third year after planting. Under average farm conditions this species may be expected to yield 100 to 200 pounds per acre, and under range conditions about half that amount.

In comparing the seed yields of these lovegrasses with those of the more common species it is important to have in mind the fact that the seed is very small and that it is harvested as clean caryopses, which gives it a per acre planting value three to five times greater than grasses that retain their husks, such as crested wheatgrass, western wheatgrass, brome and side-oats grama.

Harvesting

In comparison with most native and cultivated grasses, these lovegrasses are easily harvested, as the seeds separate readily from the shuck and yet hold on long enough ordinarily to permit the use of mechanical harvesting methods. All three species are adapted to combining, which has proved the most generally efficient and least expensive method of harvesting the seed in quantity. The small combine (3- to 5-foot cut) operated by the power take-off from a light tractor, has been found most generally satisfactory (fig. 30). It is necessary, however, that the wind from the fan be reduced to a minimum or cut off entirely to prevent the seed from being blown out with the chaff, that a fine-mesh, round-hole screen be used, and that the machine be otherwise adjusted to accommodate the very small seed. Screen sizes of 1/16-inch to 1/12-inch have been found generally satisfactory when the seed is dry and threshes out readily, but slightly larger mesh usually is necessary if the seed is a little green or damp. On account of the toughness of the grasses at this stage, especially weeping and Boer lovegrasses, it is important that the sickle be sharp and be operated at a high speed. Also, the fact that

the leaves are green and heavy during the harvest period, encouraging clogging of the operating parts, makes it necessary that the sickle bar be raised as high as practicable.

These grasses also may be satisfactorily harvested with regular small-grain binder and header equipment, leaving the grass in stacks or windrows to be threshed and cleaned as separate operations. In using this type of machine, less shattering occurs if the grasses are harvested immediately after the seeds have matured and are al-



FIGURE 30.—Combining the seed crop of Lehmann lovegrass grown under irrigation on the Papago Indian Reservation, Pima County, Ariz. The combine has proved the most satisfactory method of harvesting all three of these lovegrasses.

lowed to cure for a few days before being threshed. On the other hand, where combine-harvester equipment is used, it is necessary that the grasses be as ripe as possible, consistent with the avoidance of undue preharvest shattering. Lehmann lovegrass shatters the least readily and may be more satisfactorily handled by mowing and hauling to a stationary threshing machine or by threshing from a stack. This method is most effective with a rolling windrower attached to the mower as raking shatters the seed badly and is not practicable.

The condition of the weather has a direct bearing upon the efficiency of the harvesting operation. Light rains followed by clear weather are of little consequence, but prolonged rainy spells or sharp beating rains not only delay harvesting but lessen the seed crop. Even light cloudiness accompanied by high atmospheric humidity interferes seriously with combining operations. Although the seed may be ready to harvest, it will not combine satisfactorily during cloudy, humid weather. Where these conditions persist unduly, the use of the binder-header type of harvesting machinery is to be preferred. To be effective, combining requires sunshiny weather.

It is most important that combine-harvested seed be spread out in a dry place and stirred at least once a day until thoroughly dried. If left sacked, the presence of green particles and less mature seed will cause sweating and molding.

Cleaning

Unlike many other good grasses which on account of persistent awns, glumes, or fluffy coverings are difficult to clean without the use of special processing equipment, lovegrass seed comes from the combine or thresher as smooth, pure caryopses. Also, because of the ability of these grasses to subdue competitive vegetative growth the presence of weed seeds usually is not a problem. Nevertheless, the seeds always contain a certain amount of fine, trashy material the removal of which is necessary before they can be planted satisfactorily, especially with a garden-type seeder. The presence of even small bits of foreign matter will clog the small openings of the seed plate and cause irregular seed distribution.

The clipper-type fanning mill will efficiently clean the seeds of all three of the lovegrasses. The major precautions necessary in operating any kind of cleaning equipment are the regulation of the speed of the fan so as not to carry the small seed off with the chaff and the use of screens of the proper mesh. A round-hole (1/20-inch diameter) screen with a blank at the bottom has been found to give good results where only the removal of inert matter is required, which is satisfactory if weed seeds are not present and seeding is to be done with the whirlwind type of seeder or with a filler or in a mixture in drills designed to plant larger or chaffy seed. On the other hand, if harvested from weedy fields, or if the garden-type seeder and low seeding rates are to be used, or if intended for the commercial market, the seed ultimately must be separated by double screens of specific sizes. While the seeds of these grasses have been found to vary somewhat in size with the locality and season, necessitating the use of screens of slightly different openings, the screen sizes given in table 16 have proved generally satisfactory for the final cleaning operation. An experienced operator may save time on larger lots of seed by using larger holes than those indicated in this table and making a second running after the bulk of the chaff has been removed.

TABLE 16—Screens found generally appropriate for cleaning seed of weeping, Boer, and Lehmann lovegrasses.

Species	Size of top screen	Size of bottom screen
Weeping lovegrass.....	1/25 inch diameter	40 x 40 mesh
Boer lovegrass.....	1/25 inch diameter	50 x 50 mesh
Lehmann lovegrass.....	40 x 40 mesh	60 x 60 mesh

SUMMARY

Major facts concerning the native habitat and characteristics of three new lovegrass accessions—weeping lovegrass (*Eragrostis curvula*), Boer lovegrass (*E. chloromelas*), and Lehmann lovegrass (*E. lehmanniana*)—together with observational data on growth behavior and response to practical application since their introduction, are presented as a basis for the evaluation of these grasses for soil conservation.

These grasses succeed under a diversity of native habitat conditions. Ecologically they occupy an initial, intermediate or dominant place in the composition of grasslands as related especially to rainfall. In the higher rainfall areas they serve as important grasses in the initial stages of grassland development, while in regions of lower rainfall they become dominant in the climax stages. They likewise colonize and assume a dominant role where the surface soil is removed or disturbed, indicating the possession of inherent prerequisites to good erosion-control grasses.

Weeping and Boer lovegrasses are of the large bunch type, while Lehmann lovegrass is smaller and layering in habit. All three are perennial, come up quickly from seed, grow fast, mature rapidly and early, form deep, dense root systems, set good seed crops, self-seed naturally, are very drought resistant and are easily destroyed by cultivation when eradication is necessary. Also, they are more easily established under adverse conditions, start growth earlier in the spring, recover more rapidly from mowing or grazing, and produce more top growth (except Lehmann lovegrass) over a given period than most native and introduced grasses with which they have been compared.

As in their native habitat, these grasses succeed under a wide variety of rainfall, soil, and temperature conditions, within the southern half of the United States. Boer and Lehmann lovegrasses, being extremely drought-enduring, have proved particularly adapted to the semiarid Southwest, and weeping lovegrass, with less drought resistance but more cold endurance, to the medium to higher rainfall sections. Weeping lovegrass, however, is adapted as well to the low-rainfall areas where limited irrigation or floodwater is available. All three grasses are suited to both range and farm use, but Lehmann and Boer lovegrasses have proved especially suitable for range revegetation and weeping lovegrass for quickly covering farm lands that are subject to retirement from cultivated crops.

Under varied field conditions these lovegrasses have proved to be excellent water- and wind-erosion-control grasses, well suited for use as general ground cover, drainageway protection, siltation barriers, strip cropping, embankment cover, and wherever the land has been disturbed or bared.

Owing mainly to the abundance and enduring quality of its top and root growth, weeping lovegrass in particular has shown distinct promise for use in rotation farming and soil building where water or wind erosion is a problem. Significantly, as relates to soil-building, erosion-resistant vegetation, is the fact that the roots of this grass are notably high in lignin, the highly decay-resistant plant constitu-

ent, and that the year-to-year accumulations of top growth are greater than those of any other grass with which it was compared.

The rapid, vigorous growth of weeping lovegrass combined with resistance to blowing sands makes it especially useful under wind erosion conditions as a companion grass for some of our good but more delicate and slower-growing native species. The lovegrass produces quick, stabilizing soil cover and at the same time gives needed protection to the other grasses until they become well established.

Indicative of its quick, efficient erosion-control value, a comparison of weeping lovegrass, with nine representative native and introduced grasses showed that it exceeded them in size and strength of roots, in the number of vegetative culms, and the amount of top growth produced the first 9 weeks after planting. Lehmann lovegrass, the earliest to mature, was first in height and percentage of top to root growth.

Lehmann lovegrass was distinctive in performance in that it proved to be the most easily established and rapid-spreading of any grass tested for revegetation purposes under the very severe, semi-desert range conditions of the Southwest and on the equally difficult burned-over lands of the Chaparral belt in southern California. In addition, it was the only grass to become fully reestablished by self-seeding upon the return of normal rainfall after being killed by prolonged drought.

Although somewhat less easy to establish under range conditions than Lehmann lovegrass, Boer lovegrass was distinctive in its remarkable ability to withstand long periods without rain when once established, having been the only grass in the range-revegetation trials of which the original stand survived a 16-month drought.

As one measure of the soil-building, erosion-resistant qualities of grass, a method was devised for determining the quantity of root growth contained in the first foot of soil. Through this means it was found that weeping lovegrass under comparable conditions slightly exceeded the native grasses of somewhat similar growth habit with which it was compared and far surpassed those of lesser size, as well as two of our best tame grasses, in the amount of underground vegetative material produced. It likewise was found to exceed in percentage of leaf-to-stem growth, within one growing season, the good native and tame grasses with which it was compared.

Chemical analyses of these lovegrasses in comparison with some of our leading native and tame species showed that the lovegrasses have relatively high feeding value and that they are most nutritious while the growth is fresh and tender. In total digestible nutrients weeping lovegrass, the only one of these grasses so tested, was found to compare most favorably with the best pasture and hay grasses and legumes, exceeding that of alfalfa hay.

Palatability trials showed that horses generally are fond of these grasses in all stages of growth, that cattle graze them readily while they are in a green, growing condition, and that sheep are the least fond of them. They are not eaten readily if, because of drought, sterile soil, or the lack of fertilization, the foliage becomes brown and tough, nor after reaching maturity in midsummer.

Due mainly to the presence of greenish, succulent basal leaf growth and comparatively high food value for the season, they furnish good

winter grazing in the warmer sections, range livestock often preferring them to the drier native grasses.

Cut before becoming mature and coarse, they make a satisfactory grade of hay which is readily eaten by horses and cattle, especially during winter if used with a concentrate such as soybean or cotton-seed cake.

Livestock pastured on these grasses have kept in good condition so long as the forage was grown and grazed in such manner as to retain its palatability and nutritive value, that is, while the grass was fresh and tender. Under comparable conditions, there was no apparent difference in the condition of animals pastured on these and on the best native and tame grasses.

By growing weeping lovegrass seedlings in large boxes provided with glass fronts, it was possible to observe the effect of top removal upon root growth. One close clipping caused complete stoppage of root elongation for 2 weeks, until the leaf growth had grown out to about three-fourths its original volume; and clipping every other day prevented almost entirely the further development of the root system, materially reduced the total top growth produced, and severely weakened the grass. Correlated with these studies, mowing established field plantings more than once in the spring reduced seed and forage production proportionately during the current growing season; and continuous, heavy grazing or frequent mowing throughout spring and summer not only materially lessened seed and forage production the succeeding year, but seriously weakened and reduced the stand of the grass.

From the above observations and the knowledge that these lovegrasses are most nutritious and palatable while their growth is fresh and tender, it is apparent that they can be utilized to best advantage for grazing (or hay) during spring and early summer and during winter, leaving the latter half of the summer for the restoration of balance between top and root growth. Likewise, it appears that close grazing for short periods at a time, with a rest between each period, gives greater pasture value with less harmful effect on the grass than continued light grazing. Obviously, also, the avoidance of grazing or otherwise removing top growth during the first growing season is necessary to insure the development of the deepest and strongest initial root system possible, which is equally essential in the utilization of a grass for erosion control or forage purposes.

All three of these lovegrasses may be planted from seed or by rooted divisions of the older plants. Because they are summer growing, they may be seeded or transplanted from early spring until as late as practicable to avoid winter injury at the northern limits of their adaptation range.

Due to the smallness, clean character, and high viability of the seeds, their seeding rates are low as compared with those of most grasses, especially so when grown for seed production or planted in mixtures with other grasses or legumes.

Although capable of establishment under more adverse conditions than most grasses, they respond to methods of seedbed preparation common to ordinary small-seeded crops—firmed soil, ample moisture, and reasonable freedom from weed competition during the first growing season. They lend themselves particularly well to soil and

moisture conservation practices with which in some sections seedbed preparation must be intimately correlated.

Fertilization has not been found necessary where these grasses are grown for erosion control except on rather sterile soils where it is needed to give them a start and hasten ground coverage. For the average soils, however, the application of fertilizer is essential for satisfactory year-to-year seed and forage yields and is particularly beneficial in maintaining high palatability and nutritive values.

The principal seed-production requirements of these grasses are reasonably good soil or fertilization, low seeding rates, row planting (except Lehmann lovegrass), sufficient rest in late summer to restore the balance between tops and roots, and removal of the older growth by the time new growth starts in the spring. The last applies as well to their utilization for grazing or hay.

Because of the smallness of the seeds, the garden-type seeder has proved the most satisfactory machine for planting these grasses, operated intact or with its essential parts mounted on a cultipacker, common drill or other farm planter. For the lowest required seeding rates, seed plates with specially drilled, smaller openings are necessary. The whirlwind-type seeder is satisfactory for broadcast seeding.

The seeds of all three grasses ripen comparatively early and, with the exception of Lehmann lovegrass, shatter readily. This necessitates watchfulness to avoid loss in harvesting. While other harvesting equipment may be used, the combine-harvester has proved the most generally satisfactory, adjusted and equipped with screens to accommodate the small seed and operated during sunny weather. Whatever the nature of the equipment used in harvesting, further cleaning of the seed is necessary to insure even distribution in planting, especially where the garden-type seeder is used.

These data show beyond question that weeping, Boer, and Lehmann lovegrasses possess qualities which give them exceptional value for soil conservation uses, including the restoration of vegetative cover to lands temporarily utilized under war conditions. The fact that they have proved relatively high in food value, palatable and nutritious when utilized at the proper growth stages, and very productive of forage appears to give them definite value as well for livestock production, especially as spring and winter pasturage. Therefore, if utilized with full understanding of their limitations as well as their possibilities, these grasses should become increasingly useful acquisitions to the farm and range.

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